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PLATINUM

BY

PAUL M. TYLER AND R. M. SANTMYERS

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By Paul M. Tyler[2] and R. M. Santmyers[3]

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INTRODUCTION

Platinum and its allied metals osmium, iridium, rhodium, palladium, and ruthenium are the most costly of the better-known metals and combine properties that make them unique among the elements. For a number of isolated uses substitutes have been found which are cheaper and quite as satisfactory; but none will replace platinum in many of its varied uses, and there is a large and growing demand for purposes for which no economical substitutes are known.

As this paper is being written the supply of platinum tends further to increase as a result of the exploitation of newly developed resources and the expansion of production from older sources. In obedience to economic law prices have declined steadily. Buyers, always reluctant to commit themselves on a falling market, have maintained a waiting attitude, and consumption trends are not clearly indicated. Should platinum again approach the price of gold, the natural tendency would be to use more of the metal. In recent years, however, the industrial and scientific uses of platinum have become subordinate to its consumption in jewelry. In matters of personal adornment the popular whim and not practical utility is the dominant factor in demand, and it does not follow that lowered prices will stimulate demand. The substitution of white gold and certain plated goods for platinum may be checked by cheaper platinum, but a fickle public that turned from gold to platinum when platinum became the more costly metal can not with certainty be expected to buy more platinum jewelry because more of the metal than formerly may now be had for the same price. The dearth of platinum during and for some years after the World War had a profound effect upon prices, and this in turn wrought important changes in the field of consumption. When prices advanced the chemical industry, formerly the leading consumer of platinum, was forced to economize in its consumption of the metal and to substitute other metals whenever it could. Somewhat similar conditions resulted in the electrical industry and in the use of platinum in dentistry. Some of these former outlets are permanently closed, and others may be reopened now that platinum prices have receded to pre-war levels, but despite the general expansion of industrial and scientific activity since 1913 the demand for platinum outside the jewelry trade has suffered a net decline. Since the metallurgy of platinum is relatively simple the reason for its high price is its relative scarcity in the earth's crust. An interesting speculation set forth by certain geologists attributes the extraordinarily high density of the interior of the earth in part to the presence of iron alloyed with substantial amounts of platinum and other related metals. In support of this hypothesis it may be said that platinum is often found in meteorites, and known deposits in the earth's crust are all of deep-seated origin. However, even if there were a high concentration of platinum in the interior of the earth it would be next to impossible at the present state of our knowledge to make it available, and the world would continue to depend for its supply on deposits found within minable depths below the surface.

For many years before 1914 the world obtained its supply of platinum metals primarily from Russia, which before the war produced as much as 300,000 troy ounces in a year, or approximately 95 per cent of the world output. Despite fluctuations due to internal political disturbances Colombia managed to account for 3 to 4 per cent, leaving the rest of the world to furnish the remaining 1 to 2 per cent.

After the World War and the Revolution of 1917 the Russian output fell off to about 20,000 to 25,000 ounces annually. In Colombia, on the other hand, the government became stable, and under the stimulus of increasing prices production advanced fairly rapidly, but even the high figure of 40,000 ounces attained in 1922 failed to compensate for the virtual collapse of Russian mining.

No marked change developed in the supply situation until 1923 and 1924, when platinum was discovered in situ in South Africa; this country soon replaced Canada as the third largest producer and in 1928 contributed 23,600 troy ounces. A slight decline in output in 1929 was anticipated due to readjustments in the industry, but plant enlargements are expected to result in an annual output of over 100,000 ounces within the next two or three years--if market conditions permit.

Canada, likewise, is expected to increase its production substantially, as a result of projected developments in the Sudbury nickel-copper industry; these proposed extensions, combined with the resumption of production from Russia, raise the question of oversupply- at least at prices that will yield a satisfactory profit to the producers.

Largely as a result of the rapidly growing use of the metal in jewelry in recent years the platinum market does not conform to the simple laws of supply and demand. The price history of platinum shows that metal rose in value from only about $5 an ounce in the eighties to $45 in 1913, skyrocketed above $150 for a brief interval in 1919 and 1920, and then after several brief attempts at recovery dropped to $65 in 1929. Early in 1930 it once more got out of hand, falling in May to about $45. An interesting deduction from available statistics is that the world has about so much to spend on platinum; when prices are high it buys a little less, and when prices are low the producers of platinum merely have to work harder to receive the same gross return.

DESCRIPTION AND PROPERTIES

The "platinum-group metals" include platinum (Pt), iridium (Ir), osmium (Os), palladium (Pd), rhodium (Rh), and ruthenium (Ru). They are all grayish-white, lustrous metals, highly resistant to corrosion, and they all melt only at a high temperature.

The accompanying Table 1 shows the relative properties of the six platinum metals, divided into two groups according to their densities.

Table 1. - Classification and Properties of the Platinum-Group Metals[1]

	Light			Heavy		
	Palladium	Rhodium	Ruthenium	Platinum	Iridium	Osmium
Atomic weight	106.7	102.9	101.7	195.2	193.1	100.9
Specific gravity	12.16	12.44	12.10	21.50	22.42	22.47
Atomic volume	8.9	8.5	8.3	9.1	8.6	8.5
Melting point	1549.2°	1950°	2450°(?)	1755°	2350°(?)	2500°(?)
Boiling point	2000°	2500+°	2700+°	4300°	4800+°	5300+°
Hardness	4.8	----	6.5	4.3	6.5	7.0
Crystal system	Isometric	Isometric	Hexagonal	Isometric	Isometric	Hexagonal
Valency	1,2,3	2,3,4	2,3,4,8	2,4	2,3,4	2,3,4,8

[1] Mellor, J. W., Modern Inorganic Chemistry: London, 1918, p. 641.

Platinum. - Platinum is white, with a grayish tinge. When pure it is very malleable and ductile and takes a very high permanent polish. Its coefficien of expansion is less than that of any other simple metal. Its electric conductivity is low (13.4 at 0°C.).[4]

Platinum is not acted upon by nitric, sulphuric or hydrochloric acid, although it is soluble in "aqua regia" (1 part of nitric and 2 parts hydrochloric acid), and in other solutions liberating chlorine, with the formation of platinum tetrachloride ($PtCl_4$). It is not acted upon by air or moisture even at high temperatures. It is, however, corroded if heated in contact with caustic alkalies, sulphides, sulphates, phosphates and arsenides. It will not amalgamate with mercury unless sodium or some other "activator" is present, differing in this respect, therefore, from gold and silver.

Platinum, in a finely divided condition, absorbs large quantities of hydrogen and certain other gases, which when thus occluded become more active; hence its value as a catalytic agent. "Platinum sponge", a gray porous form of the metal, is obtained by reducing the double chloride of platinum and ammonium. "Platinum black", however, is an even more active absorbent of gases; it is a soft, dull-black powder obtained by reducing and precipitating platinum metal from its solutions. Platinized silica gel likewise is an effective catalyser used in sulphuric acid manufacture, and there are other means for increasing the surface and reducing the weight (and hence the cost) of platinum-containing masses used to stimulate chemical reactions.

Iridium. - Iridium is a brilliant white metal, brittle at ordinary temperatures but malleable at a white heat. It is slightly heavier than platinum and much harder. Its fusion point is very high - about 2350° C. - and under ordinary conditions it is not attacked by any acid, including aqua regia. At 1100° C. it begins to oxidize to a purple oxide.

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[4] Thorpe, Edward, A Dictionary of Applied Chemistry: London, vol. 5, 1924, p.330.

Next to platinum itself, iridium is probably the most useful of the whole group; it is used especially to alloy with platinum to give it the hardness necessary for many technical applications.

Osmium. - Osmium, likewise, is a hard, brittle bluish-gray metal. It is the heaviest known material (specific gravity, 22.47). It is the hardest and the least volatile of the group and also has the highest melting point. It oxidizes easily, however, and the tetroxide fumes which it gives off are very poisonous. Aqua regia does not attack crystalline osmium; but it does dissolve the amorphous variety, which is even more readily soluble in fuming nitric acid.

Osmiridium or Iridosmine. - This is an alloy of iridium and osmium and occurs naturally in hexagonal crystals or flattened grains of lighter color than platinum. It may contain 40 to 77 per cent of iridium and 20 to 50 per cent of osmium. If the iridium predominates the alloy is called Nevyanskite, and Siserskite if the osmium content is high. It is distinguishable from platinum by the brittleness of the flakes. Siserskite gives off a pungent odor, if strongly heated, caused by the volatilization of osmium. Osmiridium has a hardness of 6 to 7 and a specific gravity of 19 to 21. Synthetic iridium-osmium alloys are also produced.

Palladium. - This metal resembles platinum but is sometimes fibrous. The color is between that of platinum and that of silver. If heated to redness in air it becomes coated with oxide, but the oxide is again reduced at a higher temperature. Palladium melts at a lower temperature than any other metal of the group, and its boiling point is also lower; it volatilizes as a greenish vapor at about 2000° C. It is malleable, ductile, and almost as soft as platinum; it is much less heavy than most of the other platinum metals, being only a little heavier than common lead.

Palladium is easily soluble in aqua regia and even in concentrated nitric acid, but not so readily in other acids. The most interesting physical property of palladium is its great ability to occlude hydrogen; if heated in this gas, it can absorb over 800 times its own volume of hydrogen and retains it until heated again in a vacuum.

Rhodium. - Rhodium is a hard, white metal resembling aluminum in general appearance. It is ductile and malleable only at a red heat. Like palladium, it is only a little heavier than lead, but its melting point is considerably higher than that of platinum. The metal when pure is practically insoluble in aqua regia, but it is attacked by chlorine and sulphur/

Ruthenium. - The third of the lighter members of the platinum group (and one of the least common) is a white metal having a higher melting point than any of the entire group except osmium, which it resembles in the formation of a volatile, poisonous tetroxide. It is scarcely acted upon by aqua regia. Its hardness (6.5) is the same as that of iridium.

USES

The uses of platinum and its allied metals are many and varied. Platinum is by far the most widely used member of the group. Either alone or alloyed with others of the group, according to the requirements for which it is to be used, it enters into numerous industries. Next to platinum, palladium is most extensively used. Iridium is third as regards quantity consumed, but on account of its frequent use for hardening platinum it is second in importance. The various applications of these and of the less well-known members of the group will be discussed separately.

Platinum

The largest use of platinum is for the manufacture of jewelry. The metal is also employed extensively in the electrical and chemical industries, in dentistry, and for a variety of miscellaneous purposes. In the early days it was used in Russia for coinage, and subsequently from time to time it has been proposed by bimetallists as a standard of value.

Jewelry. - During recent years the use of platinum in jewelry has been increasing rapidly, absorbing approximately 90,000 troy ounces annually. Pure platinum is used to a great extent in making fine chains and crown settings for diamonds. No metal setting for diamonds is so artistic as platinum, and the manufacturing jeweler much prefers to work in this metal than in any other. Alloys containing up to 25 per cent of iridium with platinum are preferable to pure platinum for some work. They are stronger and harder and can be much more finely chased than gold or any alloy of platinum with another metal, but being less ductile than pure platinum are not so desirable in a mounting in which gems have to be reset.

Platinum containing 5 to 10 per cent of gold is highly elastic, but this quality disappears if the amount of gold present is increased; with 20 per cent gold the alloy is quite brittle and therefore useless for jewelry. Platinum alloys of a golden color have been used in jewelry and some of them are much more durable than gold, but they are not in great demand, as the platinum-colored alloys are usually preferred.

Electrical. - In the electrical industry platinum is largely used for contact points, in telegraph and telephone apparatus, and in magneto-contacts. A common use at one time was for the lead-in wires of incandescent lamps and for the spark-plug points of internal-combustion engines, but other and cheaper metals are now used instead.

Platinum electrodes are used in chemical laboratories and in small-scale commercial electrochemical work, and the Smee Battery cell is made in part of a plate of silver coated with platinum. In electrical furnace work the resistance wire was formerly made usually of platinum, but molybdenum is now used instead.

The construction of pyrometers for measuring heat temperatures in furnaces vary much in detail, some being based on optical principles and others on the thermal or electrical properties of metals or other substances. The pyrometer of Le Chatelier is made of a thermoelectrical couple consisting of a platinum wire and an alloy wire made up of 10 per cent rhodium and 90 per cent platinum, while the pyrometer of Sieman is in part constructed of a coil of platinum. Two other combinations for thermocouples are pure platinum combined with platinum-rhodium alloy and with platinum-iridium alloy.

Chemical Industry. - In the chemical industry platinum is largely used for catalyzers in the manufacture of sulphuric, acetic, and nitric acids; for stills for the final concentration of sulphuric acid; in the electrochemical industry; and as chemical ware in the form of crucibles, dishes, evaporating pans, etc.

Platinum catalysts may contain 7 or 8 per cent of the metal, while in others not more than 0.2 per cent of the metal is present. The contact process for making sulphuric acid has increased greatly within the last 10 or 15 years, and this rapid growth has accounted for large quantities of platinum; from 500,000 to 600,000 ounces of the metal are said to be now in use as contact mass, but future demands from this source are affected by the growing tendency to use contact masses containing relatively small percentages of platinum or none at all. Vanadium pentoxide catalysts have been employed successfully at various plants in the United States and abroad and have the advantage that they are less readily "sickened" by arsenic and other impurities. Platinum stills, often lined with a layer of gold, are used to some extent in evaporating ordinary chamber acid to high-strength acid.

One of the processes for making acetic acid is the rapid oxidation of alcohol by the aid of either spongy platinum, platinum black, or platinized asbestos. If heated platinum in either of these finely divided forms is in contact with a mixture of air and alcoholic vapor the formation and condensation of acetic acid and water takes place at once. The process is very effective and gives a pure product, but for one reason or another it has not been used on an extensive working scale.

A growing demand for platinum catalyzers is expected in connection with the oxidation of ammonia into nitric acid.

Dentistry. - Platinum alloys for dental work must be hard and unaffected by organic acids. They generally contain platinum and silver and sometimes gold or palladium, as shown in Table 2, Alloys of Platinum, although they do not compare favorably with pure platinum or pure gold, to which a little copper is added to give the necessary hardness. Molybdenum is sometimes used for the rivets and pins of artificial teeth, in which case it is thickly plated or rolled with platinum sheet.

Miscellaneous. - In X-ray work a barium platino-cyanide compound has the property of becoming fluorescent. Used as a coating upon a projecting screen it converts the X-rays and ultraviolet light rays into visible radiations.

Potassium platinochloride mixed with ferric oxalate is used in photographic paper. Where the sensitized paper is exposed to light under a negative the platinum is reduced to metal and becomes fixed on the paper; elsewhere the platinum salt remains soluble and is washed out of the paper.

Platinum is used as a constituent of a non-magnetic alloy substitute for steel in watches, for making permanent colors in pottery, in chronometer and theodolite parts, for standard assay and chemical weights, and standard measurements for length. Self-lighting lamps, igniters for Davy glow lamps, parts of apparatus used in physical laboratories to illustrate the properties of light, heat, electricity and radioactivity, and catalyzers for the oxidizing of oils to fats in the manufacture of soap also use platinum in some form or other.

Iridium

Owing to its unique qualities iridium is used principally as an alloy with platinum for hardening purposes. Jewelers' platinum usually contains 10 per cent iridium, and in the electrical industry an alloy composed of 15 to 50 per cent iridium is employed. Alloys with up to 10 per cent of iridium are ductile and malleable.

The metal is used in the manufacture of fountain-pen points, for which purpose the grains require careful selecting. Iridium is best adapted for this purpose, as it is very hard and withstands abrasion, and the writing ink has little or no chemical effect upon it. It is also used for standard weights and contact points and is suitable for sharp surgical instruments. Gold needles with soldered iridium ends are employed for stitching wounds. It is also used in photography.

Palladium

This metal has its chief value as a substitute for platinum, in palladium-gold alloys, which are used extensively in dentistry, and in jewelry and chemical ware. It is also utilized in the manufacture of astronomical instruments and watches. As metal is not altered or discolored by exposure to air or hydrogen sulphide, it is often used for plating, and because of its relatively low melting point it is employed for soldering platinum metals. The use of palladium as a catalyzer is well known, particularly in the production of fixed nitrogen from the air and in the sulphuric acid contact process.[5]

Osmium

On account of the poisonous nature of its vapor the extraction of osmium is costly and dangerous, and there is now little or no market for the metal. It was formerly widely used for the manufacture of incandescent lamps. Osmic acid is used for staining anatomical preparations in microscopic work.

Ruthenium

Ruthenium, like osmium, has little or no commercial value. The metal possesses the disadvantages of being brittle and easily oxidized.

Rhodium

Rhodium likewise has few uses commercially, although it is employed occasionally alloyed with platinum. The alloy, containing 10 per cent rhodium, is used not only for one of the thermocouples of certain pyrometers but also in laboratory utensils.

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[5] Baker & Co., Inc., Data Concerning Platinum: 14th ed., 1921, p. 8.

PLATINUM ALLOYS

Platinum readily forms alloys with a number of other precious metals as well as with numerous base metals. Only a few of such alloys, however, have industrial importance.[6]

An alloy of platinum and iridium in the proportion of 90 per cent platinum and 10 per cent iridium is widely used in jewelry and was chosen by the French Government for the standard meter length. It is very hard and elastic and is unaffected by air. Similar alloys, containing 15 to 20 per cent iridium, have been subsequently used for standard measures of length and weights. Alloys of platinum with 10 per cent iridium or rhodium are used in thermocouples to measure high temperatures.

Numerous alloys of platinum and silver are used in the manufacture of jewelry and watches, while some copper is mixed with this alloy for the same uses. Copper alloys with platinum readily, resulting in either white or yellow metal, depending on the amount of copper used.

Alloys of platinum and silver are used in the electrical industry and in dentistry. In the manufacture of electrical resistance instruments an alloy of 34 per cent platinum and 66 per cent silver is considered standard, while one containing 20 to 30 per cent is used extensively in dentistry. Alloys of platinum and gold, however, are also used for this purpose. Table 2 enumerates the principal alloys of platinum and palladium.

PLATINUM SUBSTITUTES

Because of the high price and relative scarcity of platinum numerous substitutes for the platinum metals have been proposed. Of these, perhaps the most nearly universal is tantalum; but tantalum has not been employed, at least extensively, in jewelry, which is the largest use. White gold and much cheaper alloys and chrome-plated articles simulate the appearance of platinum and are used in jewelry; in a broader sense platinum must compete in the popular fancy with many other materials, widely different in nature and appearance, used in articles of personal adornment.

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[6] Gowland, W., The Metallurgy of the Nonferrous Metals: London, 1914, p. 341.

Table 2. - Alloys of Platinum

	Platinum (per cent)	Copper (per cent)	Silver (per cent)	Gold (per cent)	Nickel (per cent)	Palladium (per cent	Other elements
Jewelry alloys:							
Palladium alloys						90	10 (rhodium)
Mock gold	20	80					
Palladium alloy			40			60	
Palladium gold		39.65	19	31		10.35	
Platine-au-titre	17		83				
Platinum-gold:							
White	40			60			
Almost white	30			70			
Do.	58.4		25	16.6			
Cooper's gold	18.75	81.25					
Do.	29	67					4 (zinc)
Cooper's pen metal	50	12.5	37.5				
Do.		50	25	25			
Cooper's mirror	9.5	58					27.5 (tin) 3.5 (zinc) 1.5 (arsenic)
Platinum substitutes							
Palau				80		20	
	20				60	10	10 (vanadium)
Cooper's	25		70		5		
Do.			70			25	5 (cobalt)
Electrical	7.5		25	67.5			
Do.	5		25	70			
Do.			25	70	5		
Proplatinum			23.5	0.75	72		3.75 (bismuth)
Pyrometer (Le Chatelier)	90						10 (rhodium)
Resistance	33.3		66.7				
Solder	27		73				
Spark plug			60			40	
Spark plug (sulphur resisting)			95			5	
Thermocouples	90						10 (iridium)
Do.	90						10 (rhodium)
Watch alloys		25	4		1	70	
Do.	63	18			17		1 (cadmium)

In the chemical industry vanadium catalysts are used to an apparently increasing extent instead of platinum, and the use of platinized silica gel and other porous substances only lightly coated with platinum tends greatly to reduce the quantity of metal employed for catalyzing purposes. As regards chemical laboratory ware and plant apparatus, many substitutes are available. For crucibles, tantalum, nickel, tungsten, and nickel-chromium and rustless iron alloys are all used, and nonmetallic substances, such as fused quartz, porcelain, and artificial corundum (alumina) likewise share the field. Palau, an alloy consisting of 80 per cent gold and 20 per cent palladium, is being marketed as a substitute for platinum for chemical ware, but due to its lower melting point and lack of resistance to chemical attack its use is limited. Rhotanum, a general name for gold-palladium alloys containing 60 to 90 per cent gold, is suitable for most chemical purposes, except for use with hot concentrated nitric acid and for electrolytic anodes. Tantalum is replacing platinum to a considerable extent in the chemical laboratory for electrodes, spatulas, stirrers, etc. This metal, which costs considerably less than platinum (about half the price of gold) has an extremely high melting point (2850° C.) and is impervious to aqua regia. Platinum-tantalum alloys containing up to 20 per cent tantalum are resistant to acids and fused potassium bisulphate and are more resistant to aqua regia than platinum itself. These alloys have a greater hardness than the corresponding platinum-iridium alloys and are less expensive.7/ Platinum spinnerets in rayon manufacture have been displaced by alloys, especially a gold alloy containing only 30 per cent platinum (or palladium).

Perhaps the greatest substitution for platinum has taken place in the electrical industry. An alloy of 60 per cent palladium and 40 per cent silver is used to resist spark erosion, as are alloys of nickel and chromium.8/ Platinite, an iron-nickel alloy (46 per cent Ni, 0.15 per cent C, and the balance iron) has the same coefficient of expansion as glass and when coated with copper is used to replace platinum as connecting wires in incandescent lamps. In ignition devices, magnetos, and sparking points, tungsten has practically entirely replaced platinum. Other metals are used instead of platinum for resistance windings of electric furnaces and for thermocouples.

For surgical and dental instruments platinum is being replaced to a certain extent by stellite and other alloys of chromium, tungsten, and cobalt.

In short, substitutes for platinum are available in almost every field. The platinum group metals with gold and silver or alloys of these two metals with the base metals are used in practically all industries in which platinum is used; but due to its unusual properties the requirements of platinum are still such that supply and demand for it are almost equal.

STAMPING LAWS

It is quite easy to debase platinum, and consumers ordinarily must rely largely upon the integrity of the seller as to the fineness of the metal. Outside of the jewelry trade platinum passes through comparatively few hands before it

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7/ Thorpe, Edward, Work cited. vol. 6, pp. 673-674.
8/ Lumb, A. D., The Platinum Metals: British Imperial Institute, London, 1920, p. 11.

enters into final consumption; but the platinum used in jewelry, now a large portion of the total, may pass through numerous hands, thereby introducing the risk of unscrupulous firms alloying the metal with cheaper metals.

This condition is taken care of in most countries for gold and silver, and in Canada a law passed April 10, 1928, (effective Jan. 1, 1929) provides for marking platinum. The new legislation took the form of an amendment to the Gold and Silver Marking Act, the title of which was changed to the Precious Metal Act, 1928. It restricts the use of the word "platinum" (or any similar description) to articles containing at least 95 per cent of platinum or platinum-iridium and provides that all such articles must carry the trademark of the manufacturer.

French hall-marked platinum must be at least 950 fine (but the average quality used by Paris goldsmiths is 970), and 950 is the standard adopted in Switzerland in 1914. In Spain (decree of November 21, 1929) all platinum articles must now be hall-marked; the minimum fineness is 940 (950 with a tolerance of 10).

HISTORY[9]

Apparently the first reference in European literature to the metal subsequently named platinum is in the book "Exercitationes Exotericae de Subtilitate" published in 1600, by Julius Scoliger, who writes of an infusible metal found in the gold and silver mines of Mexico and Panama. The earliest known reference to platinum by name was in a report published by Don Antonio de Ulloa y Gracia de la Torre, concerning an expedition he made with a French astronomical mission to South America in 1735.

The first large quantity of platinum, probably secured in Jamaica, was taken to England by Charles Wood in 1740. By 1750 the properties of the metal were fairly well known. In 1783 the first malleable platinum ingots were produced by hammering white-hot platinum sponge in an iron mold.

The demand gradually tended to outgrow the few ounces available for scientific research, but about 1819 heavy white metallic grains were found in the auriferous gravels of the Ural Mountains between European and Asiatic Russia, and in 1823 these were proved to be platinum. Rich deposits were found shortly thereafter.

The Russian platinum coinage, begun in 1828 in the reign of Nicholas I, consisted of 3-ruble, 6-ruble, and 12-ruble pieces worth (at par) $2.40, $4.80, and $9.60 according to the value of the ruble at that time; the coins contained about 2 per cent iridium. As the 3-ruble piece weighed 10.31 grams the metal was considered to be worth but 23 cents a gram ($7.15 a troy ounce). By ukase of June 22, 1845, the further coinage was stopped. This was due to the rise in the value of platinum and the subsequent exportation of the coins for their metal worth. The total amount was as follows:

9/ Many of these historical data are taken from "The Platinum Metals" by E. A. Smith (Pitman & Sons, London) who gives credit to Roscoe & Schorlemmer's Chemistry, vol. II.- The Metals.

Table 3.- Platinum Coinage in Russia

Denominations	No. of pieces	Weight, grams	Troy oz.	Value (at par)
12 ruble	3,474	143,545	4,615	$32,997
6 ruble	14,847	406,739	13,076	93,493
3 ruble	1,373,691	14,190,228	456,216	3,261,944
TOTAL	1,392,012	14,740,512	473,907	$3,388,434

Nominally these coins were worth about $3,400,000, but later the metal came to be worth many times this sum, and it seems probable that the great demand for platinum for electrical uses in the sixties caused the melting down of most of these coins, for they are now extremely rare.

ORES AND MINERALS

Until the Bushveld deposits of South Africa were opened up the platinum metals had been found almost exclusively in the native or elemental state. The only exceptions were sperrylite, a platinum diarsenide ($PtAs_2$), and laurite, a sulphide of ruthenium and osmium (probably RuS_2), the latter being found in the platinum-bearing gravels of Borneo. The platinum deposits of the Transvaal, in addition to furnishing extremely large crystals of sperrylite, have yielded two entirely new minerals, cooperite and stibio-palladinite.

Crude platinum usually occurs in nature as water-worn, rounded, or flattened grains or irregular nuggets, or, very rarely, as cubes or octahedra, together with brighter, almost micaceous flakes of the alloy of iridium and osmium known as osmiridium or iridosmine.[10] True nuggets are extremely rare, but nuggets of unusual size have been found. Two very large ones weighing 22½ and 21 6/10 pounds, respectively, were found in the platiniferous regions of the Ural Mountains in Russia, while one weighing 2 pounds was found in Colombia. Platiniridium, practically free from osmium, is also commonly associated with the ordinary crude platinum, while native palladium occurs with native platinum and in association or alloyed with gold and in some copper-nickel ores.

Sperrylite occurs as a rule in minute, well-formed, tin-white crystals, which are cubic with the same degree of symmetry as iron pyrites. It was found in 1889 as a loose crystalline powder filling small pockets in decomposed pyritic ore at the Vermillion gold mine in the Algoma district (22 miles west of Sudbury, Ontario), Canada. The platinum detected in small amounts in the pentlandite and nickeliferous pyrrhotite of the same district is perhaps present in sperrylite.

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[10] Thorpe, Edward, Work cited. vol. 5, 1924, p. 325.

Other localities in which sperrylite has been found are Wyoming and North Carolina in the United States, British Columbia in Canada, Siberia, and South Africa, but outside of South Africa sperrylite is an exceedingly rare mineral. In the sulphide platinum ores in the Transvaal, however, it is widely distributed. The most remarkable occurrence is in the pegmatite deposits at Tweefontein, in the Potgietersrust district, which has yielded well-formed crystals up to 1.85 cm. across. According to analyses the sperrylite from the Transvaal is considerably poorer in arsenic than that from Canada and elsewhere. The mineral is highly resistant to atmospheric weathering, even in the presence of acid solutions; the crystals, which have been found imbedded in gossan derived from complete oxidation and leaching of copper-nickel-iron sulphides, are brilliant and unaltered.

Cooperite, a platinum sulpharsenide, $Pt(AsS)_2$, is widely distributed in the ore of the Merensky horizon, in the Bushveld Complex, and was first recognized by R. A. Cooper, after whom it was named.[11] This mineral occurs in minute subhedral and anhedral grains in the sulphide ore of the Merensky horizon, some of the grains being almost submicroscopic. The grains are grayish-white, or yellowish-white, with a bright metallic luster. No complete crystals have as yet been found. The mineral has remarkable chemical properties. It is quite insoluble in acids, even prolonged treatment with aqua regia having no effect on it. On being heated to even a moderate temperature in a glass tube or on platinum foil it gives off sulphur and arsenic, leaving a purely metallic residue which has a peculiar reddish-bronze tarnish. This residue is fairly readily soluble in aqua regia and consists predominantly of platinum with a smaller amount of palladium.

The following is an analysis of the mineral:[12]

	Per cent
Platinum	64.2
Palladium	9.4
Sulphur	17.7
Arsenic	7.7

Stibio-palladinite likewise has so far been definitely identified only in the Potgietersrust district, Transvaal, South Africa. It occurs in irregular rounded grains, up to 2 mm. across, which sometimes show crystal faces. It is white with a peculiar yellowish-pink or bronze-pink tint. It is isotropic and appears thus to crystallize in the isometric system. Like cooperite, it is much softer than sperrylite. It gives up antimony when heated in a glass tube and is fairly readily soluble even in dilute hot aqua regia.

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[11] Wagner, P. A., Sperrylite: Proc. Geol. Soc. South Africa, March 29, 1926.

[12] Wagner, P. A., Platinum Deposits and Mines of South Africa: Edinburgh, 1929, p. 15.

A chemical analysis by H. R. Adams showed:[13]

	Per cent
Palladium	70.4
Antimony	26.0
Insoluble	1.4
$Fe(AsFe_2O_3)$	.9

It is of interest to note that in the contact metosomatic and pegmatitic deposits north-northwest of Potgietersrust stibio-palladinite and sperrylite occur side by side, the complete segregation of platinum and palladium being very remarkable.

The "platinoids" or metallics saved in milling the ores in the Potgietersrust, as reported by the operating company during the first quarter of 1930, contained platinum and palladium in the ratio of 6.5 to 1, along with a fraction of 1 per cent of other platinum metals and a relatively small amount of gold. In the concentrates, however, the palladium content slightly exceeded the platinum content. The accompanying Table 4 gives the analyses of crude platinum from the other more important platinum-producing countries. As is shown, crude platinum ordinarily contains 70 to 90 per cent of that metal, along with variable amounts of other metals of the same group and usually substantial amounts of iron and small amounts of other impurities, notably copper.

Table 4. - Analyses of Crude Platinum[1]

	Pt	Ir	Os	Rh	Pd	Ru	Au	Cu	Fe	Osmi-ridium	Sand
Crude platinum											
Choco (Colombia)	86.2	0.85	-	1.40	0.50	-	1.00	0.60	7.80	0.95	0.95
	(85.5	1.05	-	1.00	.60	-	.80	1.40	6.75	1.10	2.95
California	(79.85	4.20	-	.65	1.95	-	.55	.75	4.45	4.95	2.69
Australia	61.40	1.10	-	1.85	1.80	-	1.20	1.10	4.55	26.00	1.20
Urals	76.40	4.30	-	.30	1.40	-	.40	4.10	11.70	.50	1.40
Urals (Nischnei-Taglisk)	75.10	2.60	2.30	3.50	1.10	-	.40	1.00	8.10	.60	-
Borneo	70.21	6.13	1.15	.50	1.41	-	-	.34	5.80	-	-
Platin-iridium											
Urals	19.64	76.85	-	-	.89	-	-	1.78	-	-	-
Brazil	55.44	27.79	-	6.86	-	-	-	3.30	4.14	-	-
Osmiridium											
Urals	10.08	55.24	27.23	1.51	Trace	5.85	-	Trace	Trace	-	-
California	-	53.50	43.40	2.60	-	.50	-	-	-	-	-
Australia	-	58.13	33.46	3.04	-	5.22	-	.15	-	-	-

[1] Thorpe, Edward, Dictionary of Applied Chemistry: London, vol. 5, 1924, p.326.

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[13] Wagner, P. A., Work cited. p. 16.

MODE OF OCCURRENCE

Platinum and its associated metals are widely distributed, although thus far they have been found in paying quantities in but few localities. Most of the world's platinum has come from placer deposits, but the mother rocks from which the deposits are derived, in the large majority of known cases, consist of basic and ultrabasic igneous rocks, including peridotites, pyroxenites, and dunites. The first two are composed of iron magnesian silicates, pyroxene, augite, and hornblende with olivine, chromite, ilmenite, and magnetite; the dunites consist principally of olivine with some chromite. These rocks are often found to have undergone more or less alteration to serpentine. Platinum has been found in quartz veins, notably at the Boss Mine, Nevada, and in a few known cases it has been derived from formations in schistose, or altered sedimentary rocks, but such occurrences are far from typical and they have always failed to yield any substantial supply at reasonable cost.

When present in serpentine platinum is usually disseminated through the rock in fine particles. It seldom occurs in a lode formation. In sedimentary rocks it usually occurs in sandstone. Where alluvial deposits have been derived from the basic igneous rocks the associated minerals are usually chromite, magnetite, ilmenite, iridium, and osmiridium. In sedimentary deposits the metal is commonly associated with quartz, copper, nickel, silver, and palladium.

Platinum has been found in certain varieties of copper ores, tetrahedrite and bournonite. Its presence has occasionally been noted in shales and even in coal, although not in recoverable quantities.

Several cases are known of platinum being present in meteorites, two well-authenticated instances having been reported from Mexico. Platinum has been shown to exist in meteoric iron from New South Wales.

ASSAYING

The recognition, separation, and correct determination of platinum in the small quantities in which it is normally found in lode deposits are by no means simple. No rough method will do, even for detection, because of the small quantities involved. As the methods employed are usually those of fire assay, similar to those used for gold and silver, it is usually necessary for the prospector or others to employ an assayer to make the determination unless the platinum is fairly coarse and can be positively identified in a gold pan. Unscrupulous assayers and others using so-called "special methods" have repeatedly reported the presence of substantial amounts of platinum in samples which do not contain the metal, except perhaps in negligible traces. Based upon such fraudulent or mistaken results, a host of unsavory platinum promotions have been offered to investors, and much money that might have been profitably risked on legitimate mining ventures has thus been lost.

It can be said quite definitely that platinum does not exist in nature in a form that can not be detected quantitatively by regular methods. Small discrepancies in results reported by different assayers are of course to be expected, and large discrepancies may occur because of the "spotty" nature of the ores themselves accompanied by inaccurate sampling, but there is no foundation in fact for an assayer reporting the presence of platinum obtained by some secret process when it can not be found by a competent assayer employing standard methods. Fanciful methods almost without exception lead to inaccurate conclusions.

In general, all reputable assayers can make platinum determinations, and there is no reason why assayers should not be conversant with reliable methods. Technical Paper 270[14] of the Bureau of Mines is devoted solely to this subject and is available to the public at a cost of only 5 cents. Report of Investigations 2228[15] of the bureau describes methods for ores carrying copper. Bulletin 694 of the U. S. Geological Survey contains references to 30 articles on assaying platinum. The whole question of fraudulent returns with numerous check determinations made by various assayers has been reviewed in Serial 2496[16] of the Bureau of Mines.

QUALITATIVE TEST

If considerable quantities of platinum metals are present(for example, in gold pan "colors") the well-known glow reaction with illuminating gas may be employed. The test depends on the catalytic effect of finely divided platinum metal in the oxidation of the gas. The following description of the procedure is taken from Schoeller and Powell:[17]

> The material to be examined is dissolved in aqua regia and the test applied without any previous separation of elements. The test is more sensitive if the solution is not too acid. A very thin piece of asbestos paper, held by one end with tongs, is alternately dipped into the solution to be tested and heated until about 0.2 cubic centimeter has been absorbed. The asbestos is then heated to redness, cooled until the redness is no longer visible, and then thrust at once, while still hot, into a stream of mixed gas and air from a Bunsen burner which is regulated to deliver the mixture at a rather low pressure. If platinum is present the asbestos glows for some time. When destroyed the property of glowing can be restored by heating to redness again. The test is made more intense by using warmed gas and is said to be sensitive to 0.002 milligram of platinum, 0.005 milligram of iridium, 0.0009 milligram of rhodium, and 0.0005 milligram of palladium but does not reveal the presence of osmium or ruthenium.

Another simple test(suitable, however only for comparatively pure material) is to evaporate the aqua regia solution to dryness, redissolve in hydrochloric acid, and boil down to a thin paste (not quite dry), and then add distilled water and a few drops of sulphuric acid. To this solution a little potassium iodide may be added which, if platinum is present, produces a characteristic wine-red coloration ranging to reddish pink in the presence of only small quantities.

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[14] Davis, C.W., The Detection and Estimation of Platinum in Ores: Tech.Paper 270, Bureau of Mines, 1921, 27 pp.

[15] Davis, C.W., The Estimation of Small Quantities of Gold, Silver, and the Platinum Metals in Material High in Copper: Repts. of Investigations 2228, Bureau of Mines, March, 1921, 5 pp.

[16] Lind, S.C., Davis, C.W., and von Bernewitz, M.W., Platinum Assays and Platinum Promotions: Repts. of Investigations 2496, Bureau of Mines, July,1923, 21 pp.

[17] Schoeller, W.R., and Powell, A.R., The Analysis of Minerals and Ores of the Rarer Elements: 1919, p. 227.

MINING OPERATIONS

Platinum rock mining has so far been undertaken on a large scale only in South Africa and there only recently. According to Wagner[18] the several types of deposits in that region fall into three main classes, namely:

(1) The small almost vertical dunite "pipes" of the Lydenberg district,

(2) The big irregular steeply-dipping lenses of the Potgietersrust district,

(3) The relatively narrow and very extensive tabular ore bodies with low to moderate dips on the Merensky Horizon in the Rustenburg and Lydenburg districts.

The first class (dunite pipes) is readily mined by opencut down to perhaps 80 feet, after which shafts are sunk at some distance from the ore zone and crosscuts driven to intersect the pipes. At one mine (the Onverwacht mine) thin reinforced concrete "mats" or platforms were built across the pipes at intervals of 50 feet; and the ore in each of the vertical blocks was removed by overhand stoping, slice by slice, followed by waste filling. Combined overhand and underhand stoping, with square sets, was employed at the Mooihoek mine. At the Driekop mine, horses of barren rock were often encountered; and these were left as pillars, the ore being extracted by shrinkage stoping.

In the great composite lenses of the Potgietersrust field, where stoping widths of 20 to 50 feet have to be carried and the dip ranges from 50 to 90°, excellent results have been obtained by a method described as "top slicing", though in the United States it would be considered as cut-and-fill system. Levels are driven at 100-foot intervals, and stoping proceeds upward along winzes or raises situated at the center of the proved ore shoots with "concomitant waste filling".

The third type, the flat-lying deposits of the Merensky horizon, are worked through incline shafts spaced at regular intervals and connected up with vertical shafts sunk in the hanging wall 1,000 or more feet from the outcrop.

MECHANICAL CONCENTRATION

Most of the platinum produced in the United States, aside from that recovered by electrolytic refiners, has been a by-product of gold mining. Much of the platinum occurs in relatively small flakes, and by ordinary methods of placer mining it tends to be carried in suspension to the tailing piles. Undercurrents in the sluice boxes, though serving to increase the saving of fine gold, are not so satisfactory for saving platinum. Burlap and canvas tables have been used with some success, and various special devices have been tried and discarded for one reason or another. Shaking tables have been used for the treatment of beach sands and also to a limited extent on dredges. The Neill jig has probably proved the most generally successful means of improving recoveries on dredges.

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[18] Wagner, Percy A., Platinum Deposits and Mines of South Africa: Edinburgh, 1929, p. 267.

The preliminary concentrates from all placer operations contain platinum in various degrees of purity mixed with a relatively heavy black sand and usually gold. In Russia the gold is removed by repeated amalgamation with mercury in wood, iron, or porcelain bowls, treating about 10 to 30 pounds at a time. At larger operations mechanical equipment may be used.

By treatment with a magnet it is sometimes possible to remove some of the impurities from black sand concentrates, leaving a residue enriched in platinum, but not infrequently the platinum itself contains so much iron that it is attracted by the magnet.

Amalgamating barrels or similar arrangements will remove the gold but platinum does not unite with mercury unless the mercury is activated in some way. In the presence of metallic sodium an amalgam will form, but as soon as the sodium is dissolved out the platinum leaves the mercury. Since the sodium in the amalgam reacts so rapidly with water, the cost is prohibitive, except in the treatment of a highly concentrated product. Another method which has been proposed19/ is to suspend the platiniferous sand in an electrolyte (containing about 0.05 per cent copper sulphate and 0.05 per cent commercial sulphuric acid) and run it over an ordinary amalgamating plate sprinkled with powdered zinc amalgam.

In South Africa20/ the concentrates from gravity concentrating machines are treated in lots of 1,000 pounds in a revolving amalgamating barrel, the amalgamation being promoted by activating agents in the form of zinc amalgam, copper sulphate, and sulphuric acid. The dirty amalgam, first obtained, is reamalgamated for 30 minutes with the same agents, after which it is pressed and treated in earthenware jars with sulphuric acid to dissolve iron and zinc. The cleaned amalgam is retorted in small pots; and the retort sponge after further panning, sorting, and acid treatment is washed and dried, yielding a saleable product containing about 70 per cent of platinum-group metals.

The Eklund process is a direct electrolytic amalgamation process said to be applicable to oxidized and sulphide platinum ores without preliminary concentration. Zinc amalgam is used to combine with the platinum, and it is preferable to apply it to an iron or nickel surface. The activator found most generally useful is an aqueous solution containing mercuric chloride, zinc chloride, hydrochloric acid, and chlorine, with or without the addition of sodium chloride. The ore must be crushed fine (minus 200-mesh), and it must

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19/ Zachert, V.J., Process for Recovering Platinum: Min. Sci. Press, vol. 117, Oct. 12, 1918, pp. 489-90.

20/ The description of South African processes are summarized largely from Oragner's book.

remain in contact with the activating solution for a long time (30 to 60 minutes) before being passed over the amalgam.

The dunitic ores yielded a 98 per cent recovery by simple gravity concentration followed by amalgamation, but the complex ores of the Merensky horizon were more difficult to treat. Simple gravity concentration and ore flotation yielded only bulky concentrates too low grade to be saleable. For the sulphide ores flotation yielded a 90 per cent recovery of the platinum metals and of the nickel and copper in the form of concentrates containing 6 to 8 ounces of platinum metals. With oxidized ore, however, all the nickel and copper were lost, and only 65 to 70 per cent of the platinum metals were saved. By the so-called Krupp process these low-grade flotation concentrates were smelted and then resmelted to produce a high-grade matte containing roughly 25.5 per cent nickel, 15.5 per cent copper, and 65 ounces a ton of platinum metals. This matte is roasted and then leached with sulphuric acid, leaving a sludge which could be smelted into a product containing 60 per cent platinum metals. Much higher extractions on these difficult ores were obtained by chlorination.

The ores of the Potgietersrust district are also treated by flotation supplemented by corduroy, shaking corduroy, and James tables. The platinum metals and minerals in this district are in a much closer state of subdivision than those developed in the Rustenberg district on the Merensky horizon. The metallics caught on the corduroy tables are re-treated on a James table and then treated with a magnet, after which they are given an acid treatment, yielding a residue assaying over 60 per cent platinum-group metals. Roughly 30 per cent of the platinum present in the ore is contained in the metallics which are shipped. The flotation concentrates, as shipped, represent only 0.8 per cent by weight of the ore treated and hence are presumably high grade.

REFINING

Crude platinum can be refined either by wet or by dry methods or by a combination of the two. The standard wet method involves dissolving the platinum in aqua regia, precipitating as ammonia platinichloride, heating to redness, and then fusing the spongy platinum with an oxyhydrogen blowpipe in a furnace made from blocks of lime or in an electric furnace. After thus removing the platinum the other metals of the platinum group are recovered from the solution and from the insoluble residue.

In theory the separation of the various platinum metals from other metals and from each other is quite simple, but the manipulation is said to be difficult and is complicated further by the precautions necessary to prevent loss of the expensive materials. As to details reference may be made to a paper covering work done at the U. S. Bureau of Standards.21/

WORLD PRODUCTION

The statistics covering the world production of platinum are unsatisfactory. This applies especially to the Russian figures, and since

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21/ Wichers, Edward, Gilchrist, Raleigh, and Swanger, Wm. H.: Purification of the Six Platinum Metals: Trans. Am. Inst. Min. and Met. Eng., vol. 76, 1928, pp. 602-630.

Russia has furnished by far the bulk of the world's platinum there is no sure basis upon which to form conclusions on the trend of output or consumption covering any considerable period of time. Available data indicate, as shown in Table 5, that world production immediately before the war averaged 214,000 troy ounces, of which Russia furnished substantially more than 90 per cent, and that in recent years (1926-1928) the world production has averaged 164,000 ounces, of which Russia furnished 55 per cent and Colombia about 29 per cent. It is quite possible, however, that the actual shrinkage in production is substantially greater even than these figures indicate. Due to smuggling and other causes the uncertainty as to Russian figures year after year has been of the magnitude of 30 to even 60 per cent. For the first decade of the present century (1900-1909) the official Russian statistics show an annual average of only 176,547 troy ounces, whereas the estimated actual total as tabulated in the annual volumes of Mineral Resources of the United States averaged 257,859 ounces. For the prewar period covered by the following table (1909-1914), the corresponding averages as calculated from the U. S. Geological Survey tabulations were 171,338 and 271,700 ounces, respectively. It will be noted that Wagner's estimate is 200,000 ounces.

Table 5. - Average Annual Output of Platinum, Troy Ounces

	Prewar[1] 1909-1914	Postwar[2] 1926-1928
Russia	200,000	90,531
Colombia	12,080	47,266
Australia and Tasmania	790	326[3]
United States	594	4,668
Borneo and Sumatra	180	-----
Burma	46	-----
Canada	33	10,390
South Africa	-----	11,070
Total	213,723	164,251

[1] Wagner, P. A., The Platinum Deposits and Mines of South Africa, Edinburgh, 1929, p. 2.

[2] Calculated from figures compiled by L. M. Jones of the Bureau of Mines.

[3] New South Wales only.

The world production of crude platinum from placer deposits only is shown in Table 6 and Figure 1. According to this table the world production as late as 1927 was somewhat less than half of the annual prewar production, due primarily to a decided decrease in Russian output. Colombia, on the other hand, is producing about four times its prewar output. Other countries, likewise, have shown favorable increases during recent years.

Table 6. - World production of Crude platinum from placers, 1900-1928, Troy Ounces1/

Year	Australasia			Borneo India and Sumatra	Canada	Colombia	British India	Japan	Philippine Islands	Russia	United States
	New South Wales	Tasmania2/	Papua								
1900						11,500				212,500	400
1901						3/ 10,000				315,200	4/ 1,408
1902						3/ 9,000				300,000	94
1903						3/ 9,500				226,000	110
1904						9,625				190,120	200
1905						5/ 29,702				200,450	318
1906						5/ 6,790				210,318	1,439
1907						5,000				142,570	357
1908						3/ 5,000				138,000	750
1909	440			500	30	6,000				6/ 264,000	672
1910	332	120		200	30	10,000				275,000	390
1911	470	272			30	12,000				300,000	628
1912	610	779			7/ 30	12,000	57			300,000	721
1913	442	1,262			50	15,000	58			250,000	483
1914	244	1,019			30	17,500	37			241,200	681
1915	55	247			100	18,000	18			124,000	742
1916	82	222			60	25,000	9	70		63,900	722
1917	259	332			80	32,000	4	127		50,000	713
1918	607	1,607			40	35,000	8/	51		25,000	647
1919	213	1,670	10		30	3/ 35,000		155		3/ 30,000	742
1920	796	2,009	9/100		25	35,000		258		3/ 35,000	692
1921	249	1,751	360		15	35,000		231		3/ 20,000	977
1922	30	1,174	100		15	40,000		150	1	10/ 27,200	1,008
1923	586	673	5/145		10	42,000		224	14	10/ 38,000	609
1924	646	365	5/119		5	46,000		145		10/ 66,841	335
1925	573	3,366	5/116		6	45,000		189	4	10/ 94,780	343
11/1926	397	3,173	5/ 49		50	12/ 44,565		198	8	10/ 92,691	286
13/1927	226	633	60		11	12/ 45,830		47	31	14/ 100,000	153
1928	354	1,627	9/ 37		49	15/ 53,531		100		16/ 78,925	528

1/ Mineral Resources of the United States (Annual), Part I. 2/ Osmiridium only. 3/ Estimated. 4/ Refined platinum, 1901 to 1908, inclusive. 5/ Exports. 6/ Estimated, 1909 to 1925, inclusive. 7/ Estimated by J. M. Hill. The Dominion Bureau of Statistics, Annual Reports, give the placer output of Canada, in troy ounces, as follows:- 1912, none; 1913, 13; 1914 none; 1915, 23; 1916, 15; 1917, 57; 1918, 39; 1919, 25; 1920, 17; 1921, 23; 1922, 12; and 1923, 7. 8/ Production less than 1 ounce (0.31 ounce). 9/ For year ended June 30 of the year stated. 10/ Figures by Geol. Comm. Russia, Annual Report, U.S.S.R., vol. 1, Leningrad, 1927. 11/ Mexico, 30 ounces; New Zealand, 31 ounces. 12/ Based on personal data to J. M. Hill. 13/ Ethiopia, 2,251 ounces; New Zealand, 33 ounces. 14/ Estimated production British Imperial Institute, London. 15/ Based on data personally communicated to author. 16/ Exports for year ended June 30.

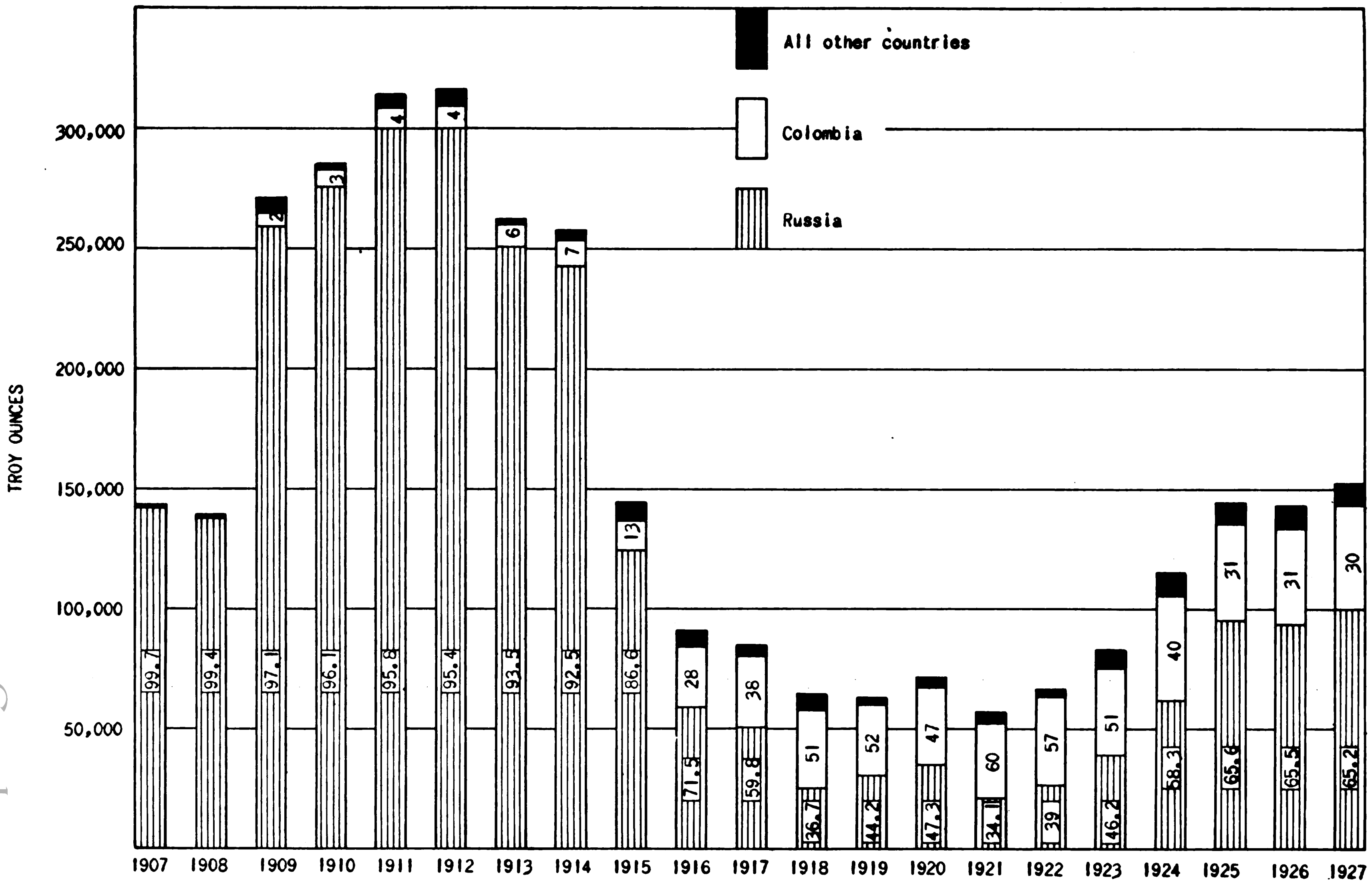

Figure 1.- World production of crude platinum from placers, 1907 to 1927

Table 7 shows the world's production of refined platinum from all sources from 1914 to 1928, inclusive. These figures represent actual sales of platinum and include by-product platinum from copper and other smelting and refining works, as well as placer production.

It will be noticed that the World War and the subsequent internal disturbances in Russia had a decided effect upon the sales of platinum. The resumption of activity in 1917 was only temporary, despite the extraordinary war-time increases in prices and the dire need of Russia for money and credit.

Since 1923, however, the world's output of refined platinum has more than doubled, reaching 181,323 troy ounces in 1928.

Table 7.- World Production of Platinum in Troy Ounces, Fine Platinum 1/

Year	Aust.	Canada 2/	Colombia	Russia	South Africa	United States 2/	Total
1914	185	----	3/ 16,264	4/ 202,000	----	1,484	219,933
1915	43	475	3/ 18,749	4/ 104,000	----	5/ 1,190	124,457
1916	62	1,040	3/ 25,592	4/ 53,000	----	5/ 2,780	82,474
1917	197	1,036	3/ 26,421	98,474	----	5/ 6,280	132,408
1918	461	705	3/ 34,266	43,181	----	5/ 9,740	78,613
1919	162	690	3/ 32,236	39,425	----	5/ 10,460	72,513
1920	640	4,345	4/ 33,500	11,323	----	5/ 11,500	61,308
1921	189	5,412	4/ 34,000	5,500	----	2,899	48,000
1922	61	4,802	3/ 43,574	22,500	----	1,988	72,935
1923	445	6,810	3/ 40,676	34,700	----	2,114	84,745
1924	490	9,186	3/ 46,533	56,900	----	3,523	116,632
1925	436	8,698	5/ 56,000	94,800	----	4,325	164,259
1926	397	9,471	3/ 44,502	92,668	4,951	4,923	156,912
1927	226	11,217	3/ 45,993	6/ 100,000	10,431	4,449	6/ 172,316
1928	354	10,483	3/ 51,305	3/ 78,925	17,828	4,631	163,526

1/ Data for 1914-1928, inclusive from Wagner, P. A., Platinum Deposits and Mines of South Africa: Edinburgh, 1929, p. 3. For the years 1926-1928 figures compiled by L. M. Jones, of the U. S. Bureau of Mines.

2/ Platinum of domestic source recovered by refiners.

3/ Exports.

4/ Estimated by J. M. Hill, U. S. Bureau of Mines.

5/ Estimated.

6/ Estimated. Includes recoveries from imported concentrates.

UNITED STATES

Occurrences

Platinum is found in only a few localities in the United States. Even in the placer deposits of California, Oregon, and Alaska (the principal producing localities), although platinum has been proved to exist over a wide area, the proportion of the platinum metals present is usually small, and the deposits could not be worked were it not for the gold content.

California.- In California platinum sands occur in small amounts in the principal placer mines of the gold belt of the Sierra Nevada, but in no place is the metal so abundant that the deposit can be worked for platinum alone. This metal undoubtedly came originally from the serpentine and peridotite or pyroxenite, which occur as intrusive masses throughout the gold belt. In many places iridosmine in small silvery-white scales is more common than platinum itself. Little or no platinum was recovered until the beginning of dredging operations on a large scale along the foothills of the mountains. The gold is recovered by amalgamation, but the platinum is in the black sand and is saved by panning. The platinum occurs in very small scales and grains, as a rule somewhat smaller than the gold, which in the dredging fields generally passes a 100-mesh screen; the quantity is very small.

A few ounces of platinum are recovered also from some of the placer mines in northwestern California in Siskiyou, Trinity, Humboldt, and Del Norte Counties. Serpentine and peridotito are abundant in this region, and the platinum is undoubtedly derived from these rocks.

The presence of platinum is characteristic of the beach sands along the Pacific coast from San Bernardino County northward to the mouth of the Columbia River. The principal beaches where platinum has been reported are Santa Barbara, Lompoc, Santa Cruz, and occasional points between Santa Cruz and the Golden Gate. The richest beaches are further north, in Humboldt and Del Norte Counties in California.

Oregon.- Most of the platinum produced in Oregon has come from the interior, where it is widely distributed in the southwestern part. The richest places appear to be near Kirby, along Josephine, Connor, and Succor Creeks, while the beaches in the vicinity of Bullards, Coos County, and Port Orford, Sixes, and Wedderburn, Curry County, are the most important.

Alaska.- Platinum metals whose bedrock source is unknown are found in placer deposits in a number of widely separated localities in Alaska, generally, however, in too small amounts and in too small particles to be recovered. Practically all of the platinum produced in Alaska comes from placers in the vicinity of Dime Creek, in the eastern part of Seward Peninsula.

Other placor deposits in Alaska in which some platinum is known to occur are on Slate Creek, in the Chistochina district, Copper River region; on Granite Creek, in the Ruby district; on Metal Creek, in the Kenai region; on several streams in the Cache Creek district, in the southwestern part of the Susitna Valley; and in some of the beach gravel on Kodiak Island. This widespread distribution and relatively high value make it well worth an operator's time to keep close watch for platinum metals in the clean-ups from placer gold-mining operations. It is certain, however, that no extensive placer deposits have yet been discovered in Alaska which are rich enough to pay for mining for the platinum content alone.

There is one lode mine in Alaska, the Saltchuck mine of the Alaska Palladium Co., on Kasan Peninsula, Prince of Wales Island, about 30 miles west of Ketchikan. The ore from the mine, which was formerly worked for its copper content, is valuable principally for its palladium, but it also contains other platinum metals and considerable gold and silver.

Wyoming.- In Wyoming, the New Rambler mine[22] situated in the Medicine Bow Range about 32 miles west of Laramie, mainly contains oxidized copper ores, and secondary covellite is contained in dioritic rock of pre-Cambrian age. Sperrylite (arsenide of platinum) is present in well-defined crystals, associated with covellite and pyrite. It is reported that the rich ores and concentrates shipped contained about 0.5 ounce of platinum and 1 ounce of palladium per ton. A secondary concentration of the platinum metals has doubtless been effected during the oxidation of the deposits. It has been reported[23] that some of the concentrates examined assayed 14.66 ounces per ton in platinum and 2.82 ounces in gold. The sample contained some silver, considerable palladium, and a small quantity of iridium.

According to an examination made in the Centennial district of Wyoming in 1923 and 1924, F. L. Hess,[24] concludes that:

> Platinum metals, in very small quantities, are undoubtedly present on Centennial Ridge.-----The mineral or minerals in which the platinum metals occur is unknown. Both sulphur and arsenic were present in one specimen tested and there is much iron stain in the schist immediately surrounding the mineral mass-----The minerals may have been sperrylito scattered through iron sulphide. In sperrylite any of the platinum metals probably may take the place of platinum.

Nevada.- A deposit discovered some years ago in southeastern Nevada, about 45 miles east of Moapa, consists of a dike of peridotite which contains copper minerals and carries a little platinum. As usual in such deposits the amount of platinum is sufficient to warrant the working of the deposit for this mineral alone. Another discovery of platinum-bearing gold ore was made in 1914, the deposit being worked previously to this date, however, for copper. This is now known as the Boss mine and is located in the Yellowpine mining district of southern Nevada.

The ore bodies at this deposit may be briefly characterized as oxidized copper shoots and gold-platinum-palladium shoots. The copper ores consist largely of chrysocolla and colloidal complexes of chrysocolla and limonite; these ores are reported to carry only minor amounts of the precious metals. The gold-platinum-palladium shoots consist of fine-grained siliceous ore carrying a small quantity of a bismuth-bearing variety of plumbojarosite (a hydrous sulphate of iron and lead). There is no fixed ratio between the content of gold and the platinum metals, or betwden the content of platinum and palladium.

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[22] Emmons, S.F., Platinum in Copper Ores in Wyoming: U. S. Geol. Survey Bull. 213, 1903, pp. 94-97.

[23] Engineering and Mining Journal, March 4, 1911, p. 460.

[24] Hess, Frank L., Platinum Near Centennial, Wyo.: U. S. Geol. Survey Bull. 780, 1926, pp. 127-135.

Production

Platinum refiners in the United States contribute about one-third of the world supply of refined new metal, but the bulk of their output is produced from crude platinum imported from foreign sources, notably Colombia.

The amount of platinum metals recovered from placer deposits in the United States is an almost negligible factor in the world supply. Much larger quantities are obtained as by-products from gold and silver bullion and copper, but even in the aggregate the output from domestic sources is of small importance as compared with domestic consumption. As may be seen from Table 8, however, the total production of these metals from all domestic sources has reached as high as 13,000 troy ounces a year; and at the high prices prevailing in 1920, when this total was reached, the value compared favorably with that of a number of other mine products. In recent years, however, the quantity has been substantially less than 10,000 ounces, and before the war it was usually less than 1,000 ounces annually. The increase since the war has been relatively large, but it should be noted that the domestic output is virtually independent of the demand for platinum, as the supply from all domestic sources is almost exclusively as a by-product of the production of gold or other metals.

Table 8.- New Platinum Metals Recovered by Refiners in the United States from Domestic Sources, 1901-1928. Troy Ounces 1/

Year	Quantity	Value
1901	1,408	$27,526
1902	94	1,874
1903	110	2,080
1904	200	4,160
1905	318	5,320
1906	1,439	45,189
1907	357	10,589
1908	750	14,250
1909	638	15,950
1910	773	25,277
1911	940	40,890
1912	1,005	45,778
1913	1,034	46,530
1914	2,500	-
1915	1,587	-
1916	3,179	-
1917	7,384	-
1918	10,693	-
1919	11,759	2/
1920	13,243	-
1921	4,800	-
1922	3,373	-
1923	3,472	-
1924	7,280	-
1925	11,209	-
1926	11,165	-
1927	8,173	-
1928	9,590	-
1929	10,886	-

1/ Mineral Resources of the United States (annual), Part I. 2/ Not available.

Crude.- Table 9 shows the production and value of crude platinum from placer operations in the United States from 1880 to 1900, inclusive. The wide variations in the value of the annual production are due to the varying content of platinum in the crude material. Table 10 shows the production from 1900 to 1928, inclusive, by States. It may be seen from these tables that the production of crude platinum in the United States has been very erratic, ranging from less than 100 ounces to as much as 1,439 ounces in a year, the bulk coming from California.

Table 9.- Production of Crude Platinum in the United States, 1880-1900, Troy Ounces[1]

Year	Quantity	Value[2]	Year	Quantity	Value
1880	100	$400	1891	100	$500
1881	100	400	1892	80	550
1882	200	600	1893	75	517
1883	200	600	1894	100	600
1884	150	450	1895	150	900
1885	250	187	1896	163	944
1886	50	100	1897	150	900
1887	448	1,838	1898	225	3,375
1888	500	2,000	1899	300	1,800
1889	500	2,000	1900	400	2,500
1890	600	2,500			

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[1] Mineral Resources of the United States (Annual), Part I.

[2] The wide variations in price up to 1901 were due to the quality of the crude product.

Table 10.- Mine Returns of Crude Platinum in the United States, 1900-1928, Troy Ounces 1/

Year	Alaska	California	Oregon	Total		Average price per ounce
				Quantity	Value	
1900	-	400	-	400	$ 2,500	$ 6.25
2/ 1901	-	1,408	-	1,408	27,526	19.55
2/ 1902	-	94	-	94	1,874	19.93
2/ 1903	-	-	110	110	2,080	18.91
2/ 1904	-	-	-	3/ 200	4,160	20.80
2/ 1905	-	-	-	4/ 318	5,320	16.73
2/ 1906	-	-	-	5/ 1,439	45,189	31.40
2/ 1907	-	300	57	357	10,589	29.66
2/ 1908	-	706	44	750	14,250	19.00
1909	-	395	277	672	12,803	19.05
1910	-	337	53	390	9,507	24.38
1911	-	511	117	628	18,137	28.88
1912	-	6/ 682	39	721	-	-
1913	-	460	23	483	18,477	38.25
1914	-	463	107	7/ 681	-	-
1915	-	8/ 600	-	742	23,500	31.67
1916	12	690	20	722	32,851	45.50
1917	81	460	65	9/ 713	64,170	90.00
1918	58	531	52	10/ 647	58,877	91.00
1919	22	683	37	742	-	-
1920	-	656	36	11/ 692	-	-
1921	65	821	91	977	-	-
1922	39	916	53	1,008	-	-
1923	7	578	24	609	-	-
1924	28	285	20	12/ 335	-	-
1925	12	312	19	343	-	-
1926	10	269	7	286	-	-
1927	20	127	6	153	-	-
1928	150	357	21	528	-	-

1/ Mineral Resources of the United States (Annual), Part I.
2/ Refined platinum, 1901-1908.
3/ Includes California and Oregon.
4/ Production by states, not available.
5/ Represents production from California, Oregon, and Washington.
6/ Includes a small output from Wyoming.
7/ Includes 111 ounces from Nevada.
8/ Estimated.
9/ Includes 107 ounces from Nevada.
10/ Includes 6 ounces from Washington.
11/ Returns not complete.
12/ Includes 2 ounces from Utah.

Refined.- The total recovery of new platinum metals from all sources, both domestic and foreign (chiefly foreign), from 1914 to 1928, inclusive, is shown in Table 11. Refined platinum accounts for the larger part of this recovery, amounting to approximately 88 per cent of the total during the past five years. The recovery of palladium by refiners during this same period averaged 9 per cent of the total, while iridium and osmiridium accounted for about 1 and 2 per cent, respectively.

Table 11.- New Platinum Metals Recovered by Refiners in the United States, 1914-1929, Troy Ounces[1]

Year	Platinum	Palladium	Iridium	Osmiridium	Others	Total
1914	3,430	2,635	64	195	-	6,324
1915	6,495	1,541	274	355	-	8,665
1916	24,518	2,885	370	315	-	28,088
1917	33,009	4,779	210	833	-	38,831
1918	54,399	4,024	465	539	326	59,753
1919	40,220	3,807	401	402	279	45,109
1920	36,015	4,309	418	409	393	41,544
1921	51,791	2,686	286	581	1,026	56,370
1922	54,142	1,943	210	1,301	122	57,718
1923	46,780	1,934	280	787	16	49,797
1924	57,827	6,065	680	1,261	174	66,007
1925	41,300	7,358	283	648	54	49,643
1926	76,154	6,437	234	2,113	43	84,981
1927	41,121	3,879	256	631	163	46,050
1928	51,427	5,148	1,658	458	348	59,039
1929	41,760	5,295	302	364	256	47,977

[1] Mineral Resources of the United States (Annual), Part I.

The quantities of the different platinum metals refined from domestic and foreign crude platinum, copper and nickel ores, and gold and silver bullion are shown in Table 12, for 1914 to 1928, inclusive. As will be noticed, the percentage of that furnished from domestic sources as compared with that from foreign sources varies considerably, ranging from 40 per cent from domestic sources in 1914 down to only 6 per cent in 1922.

Table 12.- New Platinum Metals Recovered by Refiners in the United States, by Sources, 1914-1929, Troy Ounces[1]

Year and kind	Platinum	Palladium	Iridium	Osmiridium	Other	Total	Per cent of total
1914 [2]							
Domestic	2,500					2,500	40
Foreign	930					3,824	60
Total recovery	3,430	2,635	64	195	-	6,324	100
1915							
Domestic						1,587	18
Foreign						7,078	82
Total recovery	6,495	1,541	274	355	-	8,665	100
1916							
Domestic						3,179	11
Foreign						24,909	89
Total recovery	24,518	2,885	370	315	-	28,088	100
1917							
Domestic						7,384	19
Foreign						31,447	81
Total recovery	33,009	4,779	210	833	-	38,831	100
1918							
Domestic						10,693	18
Foreign						49,060	82
Total recovery	54,399	4,024	465	539	326	59,753	100
1919							
Domestic						11,759	26
Foreign						33,350	74
Total recovery	40,220	3,807	401	402	279	45,109	100
1920							
Domestic:							
Crude						488	
Ore						1,092	
Gold & copper refining						11,663	
						13,243	32
Foreign						28,301	68
Total recovery	36,015	4,309	418	409	393	41,544	100

Table 12.- New Platinum Metals Recovered by Refiners in the United States, by Sources, 1914-1929, Troy Ounces[1/] -(Continued)

Year and kind	Platinum	Palladium	Iridium	Osmi-ridium	Other	Total	Per cent of total
1921							
Domestic:							
Crude	580	3	99	119	12	813	
Ore	1	492	-	-	-	493	
Gold & copper refining	2,318	1,165	11	-	-	3,494	
	2,899	1,660	110	119	12	4,800	9
Foreign:							
Crude	46,973	302	110	462	758	48,605	
Gold & copper refining	1,919	724	66	-	256	2,965	
	48,892	1,026	176	462	1,014	51,570	91
Total recovery	51,791	2,686	286	581	1,026	56,370	100
1922							
Domestic:							
Crude	297	-	71	512	11	891	
Gold & copper refining	1,701	777	4	-	-	2,482	
	1,998	777	75	512	11	3,373	6
Foreign:							
Crude	51,764	525	114	789	7	53,199	
Gold, nickel, & copper refining	380	641	21	-	104	1,146	
	52,144	1,166	135	789	111	54,345	94
Total recovery	54,142	1,943	210	1,301	122	57,718	100
1923							
Domestic:							
Crude platinum	247	-	42	91	5	385	
Ore	2	11	-	-	-	13	
Gold & copper refining	1,865	1,176	33	-	-	3,074	
	2,114	1,187	75	91	5	3,472	7
Foreign:							
Crude	44,318	255	205	696	11	45,485	
Ore	32	-	-	-	-	32	
Gold, nickel, & copper refining	316	492	-	-	-	808	
	44,666	747	205	696	11	46,325	93
Total recovery	46,780	1,934	280	787	16	49,797	100

Table 12.- New Platinum Metals Recovered by Refiners in the United States, by Sources, 1914-1929, Troy Ounces[1] -(Continued)

Year and kind	Platinum	Palladium	Iridium	Osmi-ridium	Other	Total	Per cent of total
1924							
Domestic:							
Crude platinum	66	-	27	16	4	113	
Ore		775				775	
Gold & copper refining	3,457	2,893	26	16		6,392	
	3,523	3,668	53	32	4	7,280	11
Foreign:							
Crude platinum	52,766	369	627	1,229	70	55,061	
Ore	1,538	2,028			100	3,666	
	54,304	2,397	627	1,229	170	58,727	89
Total recovery	57,827	6,065	680	1,261	174	66,007	100
1925							
Domestic:							
Crude platinum	136		36	39	3	214	
Ore		2,842				2,842	
Gold & copper refining	4,189	3,952		12		8,153	
	4,325	6,794	36	51	3	11,209	23
Foreign:							
Crude platinum	36,740	259	237	597	51	37,884	
Gold & copper refining	235	305	10			550	
	36,975	564	247	597	51	38,434	77
Total recovery	41,300	7,358	283	648	54	49,643	100
1926							
Domestic:							
Crude platinum	96	1	23	13	7	140	
Ore		3,330				3,330	
Gold & copper refining	4,827	2,856	3		9	7,695	
	4,923	6,187	26	13	16	11,165	13
Foreign:							
Crude platinum	32,668	250	208	2,100	27	35,253	
Gold & copper refining	38,563					38,563	
	71,231	250	208	2,100	27	73,816	87
Total recovery	76,154	6,437	234	2,113	43	84,981	100

Table 12.- New Platinum Metals Recovered by Refiners in the United States, by Sources, 1914-1929, Troy Ounces[1] -(Continued)

Year and kind	Platinum	Palladium	Iridium	Osmiridium	Other	Total	Per cent of total
1927							
Domestic:							
Crude platinum	84	1	46	30	3	164	
Ore		108				108	
Gold & copper refining	4,365	3,528			8	7,901	
	4,449	3,637	46	30	11	8,173	18
Foreign:							
Crude platinum	36,672	242	210	601	152	37,877	
Ore							
	36,672	242	210	601	152	37,877	82
Total recovery	41,121	3,879	256	631	163	46,050	100
1928							
Domestic:							
Crude platinum	209	1	54	43	14	321	
Ore	1					1	
Gold & copper refining	4,421	4,761	31		55	9,268	
	4,631	4,762	85	43	69	9,590	16
Foreign:							
Crude platinum	46,784	386	1,573	415	78	49,236	
Ore	12				201	213	
	46,796	386	1,573	415	279	49,449	84
Total recovery	51,427	5,148	1,658	458	348	59,039	100
1929							
Domestic:							
Crude platinum	369	2	17	53	-	441	
Ore	2	-	-	1	-	3	
Gold & copper refining	5,249	5,056	27	-	110	10,442	
	5,620	5,058	44	54	110	10,886	23
Foreign:							
Crude platinum	36,140	237	258	310	146	37,001	77
Total recovery	41,760	5,295	302	364	256	47,977	100

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[1] Mineral Resources of the United States (Annual), U. S. Bureau of Mines, Part I.

[2] Includes 930 ounces from foreign sources, not reported elsewhere.

Secondary Metals.- Considerable quantities of the platinum metals are reclaimed annually from secondary sources. About 85 per cent of the total during recent years has consisted of platinum. There is some duplication in the figures, as some of the same metal may be reported over and over again. The platinum in certain kinds of chemical ware, which undergoes severe use, may be reclaimed and made over several times in a year.

Table 13 shows the quantity of platinum metals recovered by refiners as secondary metal for 1914 to 1929, inclusive.

Table 13.-. Recovery of Secondary Platinum and Allied Metals, 1914-1929
Troy Ounces 1/

Year	Platinum	Palladium	Iridium	Others	Total
1914	2/ 40,698	2/ 1,500	2/ 129	18	42,345
1915	2/ 42,149	958	863	-	43,970
1916	2/ 45,156	1,284	1,535	-	47,975
1917	59,007	3,347	9,832	-	72,186
1918	40,378	1,795	3,410	-	45,583
1919	54,545	3,467	3,504	-	61,516
1920	51,255	3,100	3,355	-	57,710
1921	39,131	4,887	1,776	229	46,023
1922	40,062	4,193	1,937	496	46,688
1923	39,152	6,246	2,021	453	47,872
1924	45,474	5,784	2,200	1,013	54,471
1925	35,578	4,680	1,827	1,189	43,274
1926	38,795	5,647	1,478	217	46,137
1927	46,127	4,244	1,810	891	53,072
1928	47,157	4,156	2,090	2,428	55,831
1929	33,638	2,057	5,120	1,944	42,759

1/ Mineral Resources of the United States, Part I.
2/ Sales.

Imports

Platinum is imported into the United States in various forms and degrees of manufacture. The different classifications, together with the imports statistics for 1928 and 1929, are shown in Table 14.

Table 14.- Imports for Consumption, 1928 and 1929.

Classification	1928		1929	
	Troy ounces	Value	Troy ounces	Value
Ores of platinum metals	686	$ 49,094	564	$ 43,152
Platinum				
Grain, nuggets, sponge & scrap	78,399	5,298,665	74,063	4,466,149
Ingots, bars, etc.	29,362	2,348,840	40,594	2,640,097
Iridium	4,212	672,384	4,470	887,893
Osmium	310	20,337)	7,977	461,540
Osmiridium	5,785	418,829)		
Palladium	13,463	427,826	24,364	532,285
Rhodium	1,887	102,120)	3,031	87,666
Ruthenium	1,090	36,496)		

In addition to the items listed in the table, platinum is imported in the form of jewelry, and statistics are available showing the value of "jewelry consisting in chief value of platinum" ($224,111 in 1928). Platinum settings for expensive stones, however, would of course not be included in this classification. There is also a provision for imports of platinum compounds, but these are grouped in a blanket classification covering salts of precious metals, including "compounds * * * of which gold, platinum, rhodium, or silver constitutes the element of chief value." The total imports under this category, however, are quite small and apparently consist mainly of silver nitrate; Germany and Switzerland are the two chief countries of origin. "Ores of platinum" were obtained in 1929 from the Union of South Africa and Great Britain, the shipment from the latter country being presumably South African concentrates. "Grains, nuggets, sponge, and scrap" imports are principally from Colombia, which accounted for over 70 per cent of the total imports under this important category in 1929. Over 20 per cent of these imports, however, was credited to Great Britain (probably transshipments). Soviet Russia and Germany also contributed substantial amounts, and there were scattered shipments from Canada, Costa Rica, Japan, Chile, and China. Next to grains and nuggets the leading item is "ingots, bars, sheets, etc." In 1929 about 45 per cent of these imports came from the United Kingdom, about an equal amount came from Russia and Germany, and the remainder came chiefly from Japan and may have been of Russian origin. More than one-half of the iridium came from Germany; Great Britain, Russia, and Colombia being practically the only other sources. Great Britain, however, furnishes nearly all of the osmium and osmiridium, palladium, and rhodium and ruthenium. Some 800 ounces of palladium were shipped from Canada, and relatively small shipments of the minor platinum metals were made from Germany and France. Only a few ounces of osmium and osmiridium were credited to Colombia.

Table 15 shows the total imports for consumption into the United States of the platinum-group metals, both manufactured and unmanufactured (except jewelry), from 1901 to 1928, inclusive. Table 16 shows these imports according to products for the same period.

Since the bulk of the domestic supply of platinum is imported, the imports reflect the general upward trend in consumption.

There has been considerable fluctuation in the quantities, however, the reductions in the depression years, 1907 and 1921, being especially marked. With the exception of 1906, when 137,928 troy ounces of platinum metals and their products, having a value of $3,788,759, were imported, the peak year for the prewar period came in 1913, when the imports amounted to 132,253 ounces, valued at $5,759,276.

Following the outbreak of the world war the imports fell away rapidly, until in 1917 only 35,724 ounces of platinum metals, having a value of $2,954,220, were imported. During the war years and in 1919 the imports consisted practically only of crude platinum, the larger part of which was from Colombia, as Russian exports had ceased.

The resumption of normal shipments was interrupted by the world-wide depression in 1921, but from 1922 to 1927 there was a steady increase in the quantity of platinum imported.

Table 15.- Platinum Metals Imported for Consumption into the United States, 1901-1929. Troy Ounces 1/

Year	Quantity 2/	Value	Year	Quantity 2/	Value
1901	74,712	$1,695,895	1915	68,778	$42,768,688
1902	88,140	1,987,980	1916	63,795	3,710,815
1903	92,808	2,055,933	1917	35,724	2,954,220
1904 3/	-	1,879,155	1918	56,756	5,167,908
1905	93,912	2,173,263	1919	68,054	6,747,447
1906	137,928	3,788,759	1920	100,546	10,617,440
1907	74,292	2,684,642	1921	78,378	5,418,464
1908	50,844	1,229,873	1922	109,998	8,981,631
1909	118,853	2,973,948	1923	106,637	10,466,705
1910	118,280	3,654,664	1924	111,359	11,030,349
1911	122,751	4,866,207	1925	125,802	13,230,148
1912	104,806	4,503,682	1926	134,797	13,451,835
1913	132,253	5,759,276	1927	148,769	12,413,494
1914	76,810	3,248,858	1928	135,233	9,357,737
			1929	155,075	9,119,479

1/ Mineral Resources of the United States, Bureau of Mines (Annual), Part I.
2/ Does not include manufactured products, vases, retorts, etc.
3/ Not reported.

Table 16.- Platinum Metals Imported for Consumption into the United States, 1901-1929, Troy Ounces[1]

Metals	1901		1902		1903		1904	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Platinum ore or crude platinum, and unmanufactured products, ingots, bars, sheets and wires.	74,712	$1,673,926	88,140	$1,950,362	92,808	$1,920,044	-	-
Manufactured products, including vases, retorts, etc.	(2)	21,969	(2)	37,618	(2)	135,889	-	-
Total		$1,695,395		$1,987,980		$2,055,933		$1,879,155

Metals	1905		1906		1907		1908	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Platinum ore or crude platinum, and unmanufactured products, ingots, bars, sheets and wires.	93,912	$1,985,107	137,928	$3,601,120	74,292	$2,508,991	50,844	$1,095,754
Manufactured products, including vases, retorts, etc.	(2)	188,156	(2)	187,639	(2)	175,651	(2)	134,119
Total		$2,173,263		$3,788,759		$2,684,642		$1,229,873

Metals	1909		1910		1911	
	Quantity	Value	Quantity	Value	Quantity	Value
Platinum ore or crude platinum, and unmanufactured products, ingots, bars, sheets and wires.	118,853	$2,557,596	118,280	$3,320,699		
Ore or crude	-	-	-	-	34,412	$1,278,239
Unmanufactured, etc...........	-	-	-	-	88,339	$3,445,250
Manufactured products, including vases, retorts, etc.	(2)	$ 416,352	(2)	$ 333,965	(2)	$ 142,718
Total		$2,973,948		$3,654,664		$4,866,207

1/ Mineral Resources of the United States (Annual), Part I. 2/ Quantity not reported.

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Table 16.- Platinum Metals Imported for Consumption into the United States, 1901-1929, Troy Ounces 1/ (Continued)

Metals	1912		1913		1914		1915	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Platinum or crude platinum, and unmanufactured products, ingots, bars, sheets and wires.	45,280	$1,781,585	48,942	$1,863,406	-	-	-	-
Platinum, manufactured products, vases,	59,526	2,552,978	69,551	3,086,110	3/72,032	3/$2,934,080	61,438	$2,341,476
retorts, etc.	(2)	169,119	(2)	90,694	(2)	46,533	(2)	73,799
Iridium.............	-	-	4,094	295,864	1,785	112,430	4,158	243,266
Osmiridium..........	-	-	151	11,872	1,348	84,363	130	5,737
Osmium..............	-	-	560	42,924	-	-	32	787
Palladium...........	-	-	8,891	364,738	1,613	69,547	3,020	103,623
Rhodium.............	-	-	64	3,668	32	1,905	-	-
Total		$4,503,682		$5,759,276		$3,248,858		$2,768,688

Metals	1916		1917		1918		1919	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Platinum or crude platinum, and unmanufactured products, ingots, bars, sheets and wires.	53,522	$3,138,087	30,207	$2,408,188	54,963	$4,949,855	54,550	$5,229,309
Platinum, manufactured products, vases, retorts, etc.	(2)	21,872	(2)	1,347	(2)	8,597	22	17,213
Iridium.............	3,346	250,705	3,619	378,678	1,126	126,282	5,808	975,174
Osmiridium..........	414	17,241	259	25,456	427	46,321	1,374	112,403
Osmium	-	-	400	23,359	-	-	2,339	132,097
Palladium	6,513	282,910	1,239	117,192	240	36,853	3,739	250,777
Rhodium	-	-	-	-	-	-	222	30,474
Ruthenium	-	-	-	-	-	-	-	-
Total		$3,710,815		$2,954,220		$5,167,908		$6,747,447

1/ Mineral Resources of the United States (Annual), Part I. 2/ Quantity not reported. 3/ Revised figures.

Table 16.- Platinum Metals Imported for Consumption into the United States, 1901-1929, Troy Ounces 1/ (Continued)

	1920		1921		1922	
	Quantity	Value	Quantity	Value	Quantity	Value
Platinum or crude platinum and unmanufactured products, ingots, bars, sheets and wires.	80,955	$8,474,499	62,097	$4,129,639	94,939	$7,790,898
Platinum, manufactured products, vases, retorts, etc.	781	4/ 94,408	63	4/ 14,120	18	4/ 9,548
Iridium	4,718	726,502	1,345	277,597	1,899	298,567
Osmiridium..........	4,473	450,241	2,603	296,277	2,165	242,637
Osmium	593	39,517	161	13,239	1,012	81,231
Palladium	6,944	612,248	11,348	629,965	9,754	537,684
Rhodium	2,053	217,385	609	53,359	111	16,227
Ruthenium...........	29	2,640	152	4,268	100	4,839
Total	100,546	10,617,440	78,378	$5,418,464	109,998	$8,981,651

Metals	1923			1924		
	Quantity	Value		Quantity	Value	
		Total	Average		Total	Average
Platinum:						
Ores of platinum metals (platinum content)...........	4,139	$428,317	$103.48	1,890	$207,905	$110.00
Grains, nuggets, sponge or scrap	46,713	4,711,687	100.86	61,952	5,937,792	95.85
Ingots, bars, sheets or plates, not less than one-eighth inch thick	35,565	3,783,033	106.37	31,871	3,678,416	115.42
	86,417	8,923,037	103.26	95,713	9,324,113	102.64
Manufacturers of, except jewelry..........	103	4,769	46.30	17	2,367	139.24
Iridium..............	1,611	276,539	171.66	1,397	214,384	153.46
Osmiridium...........	1,174	150,074	127.83	1,446	174,460	120.65
Osmium...............	1,462	147,154	100.65	350	38,931	111.23
Palladium............	14,578	857,071	58.70	10,388	624,478	60.12
Rhodium..............	805	86,569	107.54	1,166	105,770	90.71
Ruthenium............	487	21,492	44.13	882	45,846	51.98
Total	106,637	$10,466,705	$ 98.15	111,359	$11,030,349	$ 99.05

1/ Mineral Resources of the United States (Annual), Part I. 4/ Includes wire to the value of $5,433, imported under 15 per cent duty, quantity not given, and "all other" to the value of $10,278 imported under 50 per cent duty, quantity not given.

Table 16.- Platinum Metals Imported for Consumption into the United States, 1901-1929, Troy Ounces[1] (Continued)

Metals	1925			1926		
	Quantity	Value		Quantity	Value	
		Total	Average		Total	Average
Platinum:						
Ores of platinum metals (platinum content).....	757	$ 71,386	$ 94.30	1,221	$ 124,668	$102.10
Grains, nuggets, sponge or scrap	58,718	5,725,015	97.50	87,162	8,683,359	99.62
Ingots, bars, sheets or plates, not less than one-eighth inch thick	47,002	5,504,068	117.10	26,585	2,995,582	112.68
	106,477	11,300,469	106.13	114,968	11,803,609	102.67
Manufacturers of, except jewelry	62	6,991	112.76	5	646	129.20
Iridium..................	2,349	586,913	249.85	3,305	411,646	124.55
Osmiridium..............	3,236	446,276	137.91	684	64,714	94.61
Osmium..................	1,050	120,845	115.09	5,457	594,042	108.86
Palladium...............	8,296	483,349	58.26	8,258	460,015	55.71
Rhodium.................	2,476	169,687	68.53	1,362	78,907	57.93
Ruthenium...............	1,856	115,613	62.29	758	33,256	50.47
Total	125,802	$13,230,143	105.17	134,797	$13,451,835	$99.79

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[1] Mineral Resources of the United States (Annual), Part I.

Table 16.- Platinum Metals Imported for Consumption into the United States, 1901-1929, Troy Ounces[1] (Continued)

Metals	1927			1928		
	Quantity	Value		Quantity	Value	
		Total	Average		Total	Average
Platinum:						
Ores of platinum metals (platinum content).....	-	-	-	686	49,094	71.57
Grains, nuggets, sponge or scrap...............	90,491	$ 7,480,869	$82.67	78,399	5,298,665	67.59
Ingots, bars, sheets or plates, not less than one-eighth inch thick	38,053	3,707,062	97.42	29,362	2,348,840	80.00
	128,544	11,187,931	87.04	108,447	7,696,599	70.97
Manufacturers of, except jewelry	37	5,812	157.08	39	3,146	80.67
Iridium..................	4,633	520,202	112.28	4,212	672,384	159.64
Osmiridium................	7,506	397,408	52.95	5,785	418,829	72.40
Osmium....................	6	277	46.17	310	20,337	65.60
Palladium.................	6,251	222,878	35.65	13,463	407,826	30.29
Rhodium...................	1,308	59,940	45.83	1,887	102,120	54.12
Ruthenium.................	484	19,046	39.35	1,090	36,496	33.48
Total	148,769	$12,413,494	$83.44	135,233	$9,357,737	$69.20

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[1] Mineral Resources of the United States (Annual), Part I.

Tariff History

Under the Tariff Act of 1930, as under previous acts, platinum and its allied metals in unmanufactured forms are admitted free of duty. Table 19 reviews the provisions made under various acts, beginning with the Tariff Act of 1883. Neither rhodium nor ruthenium was mentioned in any of the tariff acts before 1909, when they were included with osmium, iridium, and palladium in a single paragraph, which provided also for native combinations of these metals with each other or with platinum.

The duties on articles manufactured from platinum have been increased progressively from 35 per centum ad valorem under the Act of 1894 to 65 per centum under the present act.

Table 17.- Rates of Duty on Platinum, Unmanufactured.

Act of-	Par.	Tariff classification	Rates of duty, specific and ad valorem
1883	762	Platina, unmanufactured........................	Free
	763	Platina, unmanufactured, and vases, retorts, and other apparatus, vessels, and parts thereof, for chemical uses.	Do.
	614	Iridium..	Do.
	623	Osmium...	Do.
	624	Palladium......................................	Do.
1890	681	Platina, in ingots, bars, sheets, and wire....	Do.
	682	Platina, unmanufactured, and vases, retorts, and other apparatus, vessels, and parts thereof composed of platinum, for chemical uses...	
	617	Iridium..	Do.
	668	Osmium...	Do.
	669	Palladium......................................	Do.
1894	589	Platina, in ingots, bars, sheets, and wire....	Do.
	590	Platinum, unmanufactured, and vases, retorts, and other apparatus, vessels, and parts thereof composed of platinum, adapted for chemical uses.	Do.
	517	Iridium..	Do.
	574	Osmium	Do.
	576	Palladium......................................	Do.
1897	641	Platina, in ingots, bars, sheets, and wire....	Do.
	642	Platinum, unmanufactured, and vases, retorts, and other apparatus, vessels and parts thereof composed of platinum, for chemical uses.	Do.
	583	Iridium..	Do.
	630	Osmium...	Do.
	631	Palladium......................................	Do.

Table 17.- Rates of Duty on Platinum, Unmanufactured (Continued)

Act of-	Par.	Tariff classification	Rates of duty, specific and ad valorem
1909	595	Iridium, osmium, palladium, rhodium, and ruthenium, and native combinations thereof with one another or with platinum.	Free
	653	Platinum, unmanufactured, or in ingots, bars, plates, sheets, wire, sponge, or scrap, and vases, retorts, and other apparatus, vessels, and parts thereof, composed of platinum, for chemical uses.	Do.
1913	517	Iridium, osmium, palladium, rhodium, and ruthenium, and native combinations thereof with one another or with platinum.	Do.
	565	Ores of * * * ; ores of the platinum metals; * * *.	Do.
	578	Platinum, unmanufactured, or in ingots, bars, plates, sheets, wire, sponge, or scrap, and vases, retorts, and other apparatus, vessels, and parts thereof composed of platinum, for chemical uses.	Do.
1922	1596	Iridium, osmium, palladium, rhodium, and ruthenium and native combinations thereof with one another or with platinum.	Free
	1644	Platinum, unmanufactured or in ingots, bars, sheets, or plates not less than one-eighth of one inch in thickness, sponge, or scrap.	Do.
1930	1699	Iridium, osmium, palladium, rhodium, and ruthenium and native combinations thereof with one another or with platinum.	Do.
	1744	Platinum, unmanufactured or in ingots, bars, sheets, or plates not less than one-eighth of one inch in thickness, sponge, or scrap.	Do.
		Platinum, manufactures of.	
1883	216	Manufactures, articles, or wares not specially enumerated or provided for in this act composed wholly or in part of * * * platinum * * * and whether partly or wholly manufactured.	45 per centum ad valorem.
1890	215	Manufactures, articles, or wares not specially enumerated or provided for in this act composed wholly or in part of * * * platinum, * * *, and whether partly or wholly manufactured.	Do.

Table 17.- Rates of Duty on Platinum, Unmanufactured (Continued)

Act of-	Par.	Tariff classification	Rates of duty, specific and ad valorem
1894	177	Manufactured articles or wares not specially provided for in this act, composed wholly or in part of any metal and whether partly or wholly manufactured.	35 per centum ad valorem.
1897	193	Articles or wares not specially provided for in this act, composed wholly or in part of * * *, platinum, * * *, and whether partly or wholly manufactured.	45 per centum ad valorem.
1909	199	Articles or wares not specially provided for in this section, composed wholly or in part of * * *, platinum, * * *, and whether partly or wholly manufactured.	Do.
1913	167	Articles or wares not specially provided for in this section, if composed wholly or in part of platinum, * * *, and whether partly or wholly manufactured.	50 per centum ad valorem.
1922	399	Articles or wares not specially provided for, if composed wholly or in chief value of platinum, * * *, and articles or wares plated with platinum, * * *, whether partly or wholly manufactured, * * *.	60 per centum ad valorem.
1930	397	Articles or wares not specially provided for, if composed wholly or in chief value of platinum, * * *, and articles or wares plated with platinum, * * *, whether partly or wholly manufactured.	65 per centum ad valorem

Exports

There are no recorded exports of ores of the platinum metals; but substantial amounts of "unmanufactured" platinum have been exported from the United States to Japan and Germany in certain years, and manufactured items, probably chemical ware, are exported to Canada and to a less extent to other countries.

Table 18.- Platinum Exported from the United States, 1916-1929 Troy Ounces[1]

Year	Unmanufactured		Manufacturers of (Except jewelry)		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
1916	1,145	97,988	(2)	83,864	—	181,852
1917	3,445	234,433	(2)	85,415	—	299,848
1918	119	13,511	(2)	23,562	—	37,073
1919	522	75,066	(2)	54,529	—	129,595
1920	1,302	177,115	(2)	111,014	—	288,129
1921	3,272	244,473	741	85,216	4,013	329,689
1922 3/	143	13,149				
4/	1,313	127,047	486	35,967	1,942	176,163
1923	1,151	128,599	592	65,073	1,743	193,672
1924	5,854	643,282	1,274	136,948	7,128	780,230
1925	16,234	1,787,122	3,537	249,975	19,771	2,037,097
1926	11,573	1,253,795	1,898	160,648	13,471	1,414,443
1927	19,923	1,577,560	1,549	128,875	21,472	1,706,435
1928	9,050	619,478	2,168	160,554	11,218	780,032
1929	2,567	193,122	1,455	112,252	4,022	305,374

1/ Mineral Resources of the United States (Annual), Part I.
2/ Quantity not recorded.
3/ Includes crude, scrap and old.
4/ Includes ingots, sheets, wire and alloys.

Domestic Stocks

Table 19 shows the stocks of platinum metals in the hands of refiners in the United States at the end of each year from 1918 to 1929, inclusive. Stocks of platinum account for about 60 per cent of the total, while those of palladium represent approximately 25 per cent of the total.

These stocks are mostly in the hands of refiners and represent manufactured products, very little of the refined metal being kept on hand in the unmanufactured state.

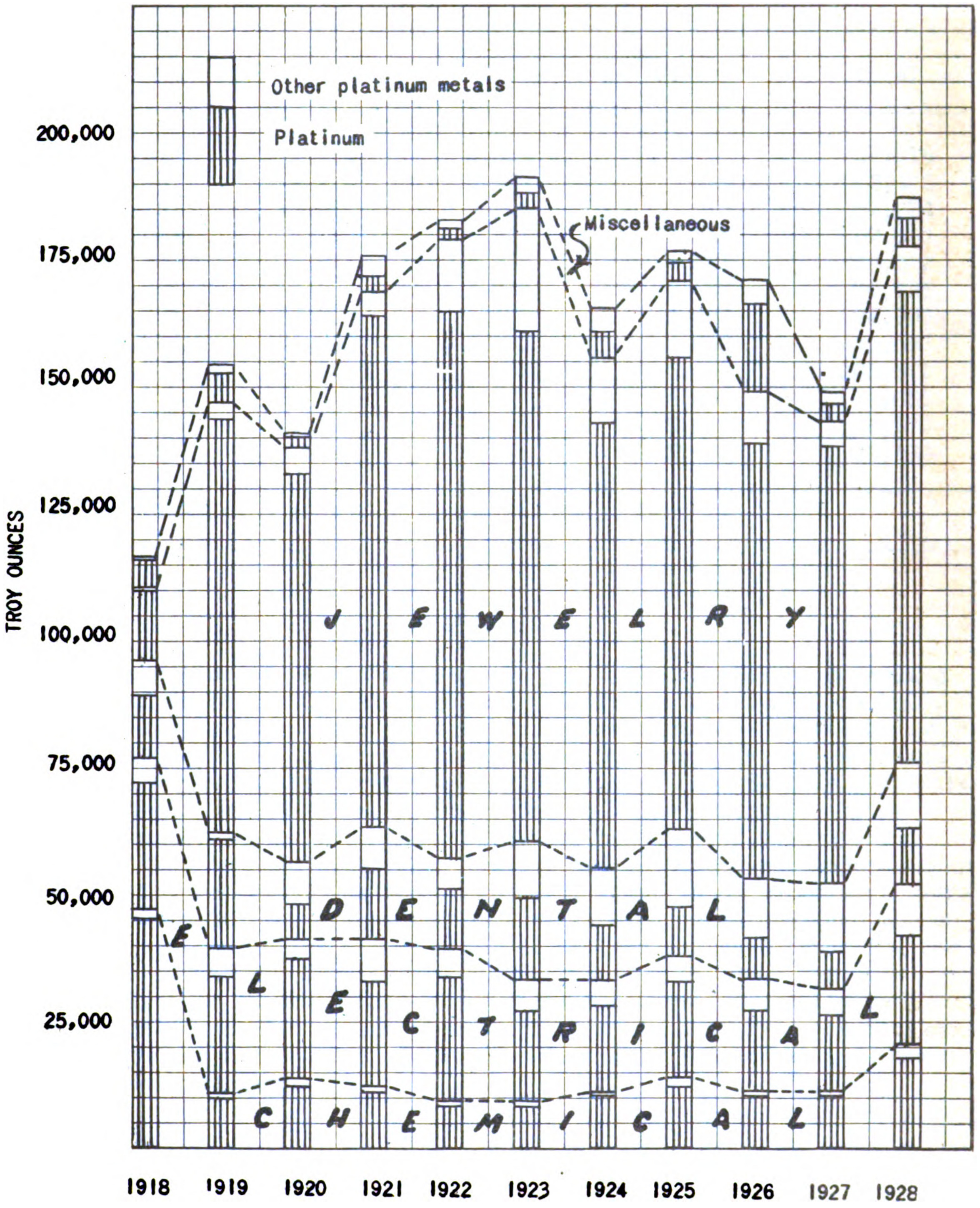

Figure 2.- Platinum metals consumed in the United States

Table 19.- Stocks of Platinum Metals in the Hands of Refiners in the United States, December 31, 1918-1929, Troy Ounces 1/

Year	Platinum	Palladium	Iridium	Other	Total
1918	51,504	10,086	3,224	-	64,814
1919	29,228	10,235	3,359	610	43,432
1920	46,747	16,565	4,196	216	67,724
1921	38,514	21,024	4,991	3,113	67,660
1922	41,900	24,975	7,559	1,583	76,017
1923	36,554	26,266	5,208	2,697	70,725
1924	40,464	27,400	3,622	3,053	74,539
1925	44,024	26,740	3,720	4,609	79,093
1926	64,203	31,950	3,933	5,485	105,571
1927	68,757	24,313	4,617	4,369	102,056
1928	45,710	23,018	4,523	5,019	78,270
1929	51,853	20,154	4,716	5,461	82,184

1/ Mineral Resources of the United States (Annual), Part I.

Domestic Consumption

The consumption of platinum metals in the United States by consuming industries is shown in Table 20, and graphically in Figure 2 for 1918 to 1928, inclusive. These figures have been compiled from data furnished to the Bureau of Mines by the refiners and do not check in every instance with the indicated total consumption, as calculated from the production and foreign-trade statistics. Much of the imported metal is included, in so far as it is desirable, by refiners and others reporting to the Bureau of Mines; but some of the imported metal, especially that handled by smaller dealers and consumers who import their own supplies, are not reported. On the other hand, there is an occasional overlap wherein the same metal may appear in the reports of two dealers, one acting in a certain type of transaction as the agent of another and both reporting the sale to the Bureau of Mines. Despite these minor sources of error the consumption data reflect at least the major movements and serve especially to bring out the largely expanded consumption of platinum in jewelry. The increasing use of palladium is also worthy of note, particularly for dental and, more recently, electrical purposes.

Table 20.- Platinum Metals Consumed in the United States as Reported by Refiners, by Industries, 1918-1928, Troy Ounces[1]

	Platinum	Palladium	Iridium	Others	Total	Per cent of total
1918[2]						
Chemical	45,391	834	717	-	46,942	41
Electrical	24,982	594	3,107	-	28,683	25
Dental	11,461	7,371	418	-	19,250	17
Jewelry	13,541	42	721	-	14,304	12
Miscellaneous	5,435	212	339	-	5,986	5
Total	100,810	9,053	5,302	-	115,165	100
1919						
Chemical	10,759	63	41	-	10,863	7
Electrical	23,875	1,283	3,534	-	28,692	19
Dental	11,047	10,311	185	-	21,543	14
Jewelry	82,397	1,460	3,145	-	87,002	56
Miscellaneous	5,602	445	596	-	6,643	4
Total	133,680	13,562	7,501	-	154,743	100
1920						
Chemical	13,226	240	43	-	13,509	9.58
Electric	23,029	1,784	2,673	-	27,486	19.49
Dental	6,413	8,898	114	-	15,425	10.94
Jewelry	77,267	593	3,108	-	80,968	57.40
Miscellaneous	3,119	418	116	-	3,653	2.59
Total	123,054	11,933	6,054	-	141,041	100.00
1921						
Chemical	12,273	45	34	-	12,352	7.01
Electrical	20,574	7,626	1,003	-	29,203	16.58
Dental	13,181	8,501	75	-	21,757	12.35
Jewelry	101,258	1,265	2,367	-	104,890	59.55
Miscellaneous	3,791	217	3,938		7,946	4.51
Total	151,077	17,654	7,417	-	176,148	100.00
1922						
Chemical	8,834	458	172	271	9,735	5
Electrical	24,988	2,735	1,537	-	29,260	16
Dental	11,651	5,535	83	0	17,269	10
Jewelry	108,527	9,852	2,588	1,190	122,157	67
Miscellaneous	2,838	636	1,064	-	4,538	2
Total	156,838	19,216	5,444	1,461	182,959	100

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[1] Mineral Resources of the United States (Annual), Part I.

[2] Figures not available prior to 1918.

Table 20- Platinum Metals Consumed in the United States as Reported by Refiners, by Industries, 1918-1928, Troy Ounces[1] (Continued)

	Platinum	Palladium	Iridium	Others	Total	Per cent of total
1923						
Chemical	8,637	485	190	266	9,578	5
Electrical	18,596	3,666	1,675	-	23,937	13
Dental	16,288	10,116	153	-	26,557	14
Jewelry	105,699	14,948	3,073	190	123,910	65
Miscellaneous	3,156	986	1,403	1,256	6,801	3
Total	152,376	30,201	6,494	1,712	190,783	100
1924						
Chemical	10,507	436	122	403	11,468	7
Electrical	16,588	3,099	1,269	-	20,956	13
Dental	11,092	10,049	131	-	21,272	13
Jewelry	87,151	12,480	2,204	746	102,581	62
Miscellaneous	5,012	2,122	634	973	8,741	5
Total	130,350	28,186	4,360	2,122	165,018	100
1925						
Chemical	12,558	383	71	685	13,697	8
Electrical	18,845	3,157	1,579	111	23,692	13
Dental	9,293	14,952	95	-	24,340	14
Jewelry	93,393	10,950	2,840	2,280	109,363	62
Miscellaneous	3,356	520	220	1,414	5,510	3
Total	137,345	29,962	4,805	4,490	176,602	100
1926						
Chemical	10,253	213	145	223	10,839	6
Electrical	16,765	3,508	1,608	185	22,066	13
Dental	8,542	11,063	131	-	19,736	11
Jewelry	85,908	7,770	2,949	454	97,081	57
Miscellaneous	17,381	2,181	581	1,751	21,894	13
Total	138,849	24,735	5,414	2,613	171,616	100
1927						
Chemical	11,010	180	101	175	11,466	8
Electrical	14,905	2,491	1,618	121	19,135	13
Dental	7,504	12,194	153	-	19,851	13
Jewelry	86,036	3,706	4,059	329	94,130	63
Miscellaneous	3,176	312	305	1,311	5,104	3
Total	122,631	18,883	6,236	1,936	149,686	100

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[1] Mineral Resources of the United States (Annual), Part I.

Table 20.- Platinum Metals Consumed in the United States as Reported by Refiners, by Industries, 1918-1928, Troy Ounces[1] (Continued)

	Platinum	Palladium	Iridium	Others	Total	Per cent of total
1928						
Chemical	18,529	1,252	113	135	20,029	11
Electrical	21,316	9,150	1,525	2	31,993	17
Dental	10,930	12,270	167	10	23,377	12
Jewelry	93,468	4,965	3,260	815	102,508	55
Miscellaneous	5,431	2,136	963	850	9,380	5
Total	149,674	29,773	6,028	1,812	187,287	100

As previously noted, the total apparent consumption of platinum metals in the United States as calculated from available statistics of production, imports, and exports, is somewhat different from the consumption figures, as calculated from reports of refiners' sales. The apparent consumption, as shown in Table 21, is somewhat larger than that shown in the previous table.

Table 21.- Calculated Consumption of Platinum Metals in the United States, 1918-1929, Troy Ounces[1]

Year	Production	Plus imports 2/	Plus secondary metal	Less exports	Inventory adjustment (plus or minus) 3/	Total available for consumption
1918	10,693	56,756	45,583	4/ 1,000	+186	112,218
1919	11,759	68,054	61,516	4/ 2,000	+21,382	160,711
1920	13,243	100,546	57,710	4/ 3.500	-24,292	143,707
1921	4,800	78,378	46,023	4,013	+64	125,252
1922	3,373	109,998	46,688	1,942	-8,357	149,760
1923	3,472	106,637	47,872	1,743	+5,292	161,530
1924	7,280	111,359	54,471	7,128	-3,814	162,168
1925	11,209	125,802	43,274	19,771	-4,554	155,960
1926	11,165	134,797	46,137	13,471	-26,458	152,150
1927	8,173	148,769	53,072	21,472	+3,515	192,057
1928	9,590	135,233	55,831	11,218	+23,786	213,222
1929	10,886	155,075	42,759	4,022	-3,914	200,784

1/ Mineral Resources of the United States (Annual), Part I.
2/ Does not include imports of jewelry.
3/ Based on stocks as reported on December 31 of each year.
4/ Estimated.

FOREIGN COUNTRIES

The important countries in which workable placer deposits are found are Russia, Colombia, Australia, and Canada, while lode deposits are worked in South Africa and Canada.

Russia

Russia is probably the best-known producer of platinum metals and prior to the war produced as much as 95 per cent of the world's output in some years. The Ural deposits of platinum, the principal of which are at Nizhni Tagilsk, Bisersk, and Gorobladodat, are all alluvial formations, while the sources of platinum are country rocks made up of serpentine, gabbro, diorite, and olivenite. The native platinum in the Urals appears to have come partly from a serpentine area, and partly from a neighboring formation made up of granite or altered sedimentary rocks. The platinum usually includes some iridium, rhodium, ruthenium and iron.

Mining.- In Russia, particularly, the mining of platinum has been carried on by primitive hand methods. It has been estimated that in 1909 some 80 per cent of the output was produced in this manner; by 1914 this had fallen to less than 60 per cent. For some time during the war and after the Revolution, dredging was practically discontinued, but since the shipment of some $2,000,000 worth of dredging equipment from the United States in 1925, only about 10 to 15 per cent of the output is said to be produced by hand-sluicing methods.

The season during which dredges may be employed in Russia is quite short, extending on the average only from the middle of April to the middle of October. In the south, in the Verkhotur and Perm areas, dredges are used in the larger enterprises, but hand mining is still carried on at the smaller mines.

In the mines where dredging is not in use the gravels are mined by opencuts; or, if the overburden is heavy, shafts are sunk. The former method is much preferred, both on account of its relative cheapness and because a better clean-up of the bed rock can be obtained. In winter the miners take advantage of the extreme cold by allowing the working to freeze and then operating on the frozen ground by thawing it with wood fires. This is necessary because the deposits in part are in very loose and watery ground and troublesome to exploit. The method is suitable for depths up to 30 feet, and in localities where the snowfall is comparatively light.

The usual types of stationary plant in use include the "botchka," or conical revolving screen; the "tchaska," or puddling machine, with a bottom of perforated-iron plates; and the "boronka," or conical screen, on which the stones and clay are turned over by a double rake. The gold is removed by amalgamation with mercury.

Production.- Platinum was first discovered in the Urals in 1823, and exploitation commenced in the following year.

The platinum industry did not really begin to develop until 1869, but from that year on the value, although subject to considerable fluctuations, has steadily increased.

The accompanying Table 22 shows the production of crude platinum in Russia for the years 1880 to 1900, inclusive, in troy ounces. The average annual production of crude platinum for this 21-year period was 143,686 ounces; the upward trend developed in the last decade of the 19th century brought the output to a maximum of 212,500 ounces in 1900. From then on until the World War, Russia's output of this metal fluctuated between 138,000 ounces (1908) and 315,200 ounces (1901). The war and the subsequent Russian revolution had a decided effect upon the production of platinum in Russia, the output in 1921 being reported at only 20,000 troy ounces.

Since that date, however, there has been a decided upward trend toward normal production, the output in 1927 being reported at 100,000 ounces; the estimated production for 1928 is about 150,000 ounces.

Table 22.- Production of Crude Platinum in Russia, 1880-1900, Troy Ounces[1]

Year	Quantity	Year	Quantity
1880	94,746	1891	149,365
1881	91,900	1892	161,234
1882	131,201	1893	179,801
1883	113,714	1894	183,664
1884	71,919	1895	155,646
1885	91,944	1896	173,838
1886	152,195	1897	200,000
1887	155,415	1898	203,100
1888	95,799	1899	206,000
1889	92,946	1900	212,500
1890	100,289		

[1] Mineral Resources of the United States (Annual), Part I.

Exports.- Table 23 shows the exports of platinum from Russia for 1901 to 1914 and 1922-23 to 1927-28. As will be noted, the exports for the past six years were far below those before the war, when exports had reached as high as 272,811 troy ounces (1910). The decided decrease in 1927-28 was the result of a decreased output, as the exports for the previous two years far exceeded production and were partly from stocks on hand. It has been stated that some of the large exports in these two years represented backing for credit rather than actual sales.

Table 23.- Exports of Platinum from Russia (1901-1914 and 1922-23 to 1927-28), Troy Ounces

Year	Quantity	Year	Quantity
1901	71,627	1911	221,198
1902	40,553	1912	222,252
1903	61,619	1913	200,658
1904	92,166	1914	82,686
1905	61,619		
1906	203,819	1922-1923	9,303
1907	156,945	1923-1924	26,077
1908	165,905	1924-1925	90,965
1909	259,645	1925-1926	127,471
1910	272,811	1926-1927	157,790
		1927-1928	76,355

Colombia

Colombia antedates Russia as a source of platinum and has contributed more to the total supply than any other country except Russia. The platinum deposits are in the northwestern part of the country. The principal source of supply is at the head of the San Juan River, which flows south and enters the Pacific Ocean just north of Buenaventura. The richest deposits occur on the Condoto, Opagado, and Tamanal Rivers, tributaries of the San Juan River. The Atrata River, which flows northward into the Gulf of Uraba (Caribbean Sea) has valuable deposits of platinum associated with gold along its upper reaches, where it is only a short distance from the head of the San Juan River. This area (the upper Atrata and San Juan Rivers), covering approximately 5,000 square miles of territory, is known as the Choco district. The stream beds in which platinum occurs are those in which Tertiary conglomerates have become eroded; in areas where this formation is still below the surface the river gravels are barren. The conglomerates are composed of rounded bowlders of basic rocks, such as diabase, peridotite, dunite, and other dark igneous rocks.

Platinum has been found in the Choco district also in serpentine rock, and the granite in this area is likewise traversed by quartz lodes containing palladium, iridium, osmium, and rhodium.

Some platinum is won in the extreme southern part of the country in the Micay River district, near the Colombia-Ecuador line.

Mining.- Colombian crude platinum contains 80 to 85 per cent platinum, the remaining 15 to 20 per cent consisting chiefly of iridium and osmium.

In the past, mining operations have been very irregularly carried on by primitive methods, but in 1928 three dredges were operated in the Condota River Valley by the South American Gold & Platinum Co. and the installation of a second hydroelectric unit on the Andagueda River had been started.[25] The native methods of working platinum wash are of some interest. Where the metal occurs in the bed of a river it is obtained by diving girls, who work down to the platiniferous gravels, removing the gravel in small wooden dishes; men are employed to wash the gravel after it has been brought to the river banks. The alluvial gravels derived from dried-up beds of ancient rivers are hand-washed with the use of the batea or flat wooden dish.

Production and Exports.- Platinum from Colombia was first introduced into Europe about 1735, but due to the difficulty of refining and melting the metal very little was produced. In colonial times and until about the middle of last century the platinum found associated with gold in the gravels of the Choco district had practically no market value and was thrown away with the black sand after amalgamating the gold.

It has been estimated that shipments of any sizable amounts were first made about the middle of the 19th century. From 1850 until 1900 the exports of platinum from Colombia may be placed at approximately 250,000 to 350,000 troy ounces, which represents fairly closely the production of that metal in Colombia.

Table 24 shows the exports of platinum from Colombia to the United States from 1905 to 1927, inclusive. The United States takes practically all of the platinum exported by Colombia, this export representing 95 to 98 per cent of the total production.

Table 24.- Exports of Platinum from Colombia to the United States (1905-1928)

Year1/	Troy Ounces	Value	Year1/	Troy Ounces	Value
1905	1,140	$21,504	1918	27,030	$2,241,744
1906	2,316	45,763	2/1918	30,543	2,630,614
1907	5,496	190,206	1919	26,046	2,303,111
1908	1,092	25,576	1920	29,853	2,880,887
1909	2,302	36,440	1921	31,840	1,951,357
1910	1,600	31,383	1922	37,230	2,936,487
1911	5,503	147,320	1923	32,278	3,162,816
1912	6,627	219,128	1924	43,463	4,033,370
1913	10,461	363,731	1925	33,595	3,019,826
1914	12,387	398,657	1926	39,004	3,490,129
1915	16,298	584,424	1927	52,050	4,398,259
1916	24,774	1,667,805	1928	52,800	3,561,722
1917	21,278	1,536,422			

1/ Fiscal year ended June 30.
2/ Calendar year.

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[25] Kunz, Geo. F., Platinum Mineral Ind. during 1928, p. 493.

Union of South Africa[26]

Platinum metals in varying quantities have been found in several districts in the Union of South Africa, and about 1921 osmiridium began to be recovered in substantial quantity as a byproduct of gold mining on the Far East Rand. The important deposits of the Transvaal, however, were not discovered until 1923 or 1924 and did not come into production until 1926. Two years later South Africa had become the third largest factor in world production and in 1929 contributed some 22,500 (estimated) ounces of platinum metals with the prospect of further increases by 1931 which would bring productive capacity up to 100,000 ounces annually.

In 1921 platinum deposits were discovered in the Waterberg district of the Transvaal, but the occurrences were so erratic that mining was suspended in August, 1926; the ores were difficult to extract, and the treatment plant operated only a few months. In 1924, however, the Lydenburg district in the same province was discovered, and during 1925 important discoveries were made in the Potgietersrust and Rustenberg districts in the norite zone of the Bushveld complex. These discoveries were followed later by others in Northern Transvaal and Southern Rhodesia. The geological relations of these deposits are widely diverse, and they are found in rocks ranging in age from the most ancient to the most recent. Geographically, however, they are confined to a belt running roughly north and south and lying between longitude E. 26° and longitude E. 30° 40'; the occurrences of the Insizwa (the most southerly) and Lydenburg (central) areas and those of the Great Dyke of Southern Rhodesia (northernmost) actually lie between longitude E. 29° 20' and longitude E. 30° 40'. Far to the north platinum and palladium are found in the gold deposits of the Kilo gold field in the northeastern part of the Belgian Congo; and still further north and deviating no great distance to the east the Abyssinian deposits may be considered likewise to be included in this great platinum belt, which apparently was genetically related to a long canal or fissure which extends almost the length of the continent and which has been reopened repeatedly to permit the egress of platiniferous material at various points and at various times. The greatest concentration of platinum occurs, however, in what is known as the Bushveld igneous complex, a vast composite body of plutonic and volcanic rocks occupying an area about 15,000 square miles in the central part of the Transvaal. In plan the area is an irregular oval; the longer axis is 280 miles in length and the shorter, 150 miles.

Wagner (p.49) has classified the various types of deposits in the norite zone of the Bushveld complex, but any geological or geographical classification is of only academic significance. From the economic standpoint only the three types of deposits (previously noted under Mining Operations, p. 18), need be considered, namely, (1) the almost vertical dunite pipes of the Lydenburg district; (2) the big irregular lenses of the Potgietersrust district; and (3) the relatively narrow and very extensive tabular flatly inclined ore bodies on the Merensky horizon in the Rustenberg and Lydenburg districts.

The dunite pipes, of which the Onverwacht mine represents the best-known example, are pipe or parsnipshaped segregations (hortonite-dunite in olivine-dunite) enriched in platinum. The core of such a deposit may average 1 ounce or more per ton in platinum, and the platinum content becomes progressively less and less as the distance from the center increases until the rock becomes too lean to work. Associated with these deposits masses of platinum-bearing dunite may also occur as irregular sheets, lenses, and "schlieren" in coarse pegmatitic diallage or diallage-ilmenite-pegmatite.

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[26] Geological data abstracted from Wagner, P.A., Platinum Deposits and Mines of South Africa: Edinburgh, 1929, 325 pp.

The Merensky horizon is in the upper part of the differentiated zone of the Bushveld complex. It is almost as regular as a coal seam, taking the form of a thin layer of dark-platinum-bearing rock (or rocks) intercalated with beds of light-colored norite and anorthosite. There is a pseudostratification that gives the formation the aspect of well-bedded sedimentary stratum. The Merensky horizon has been traced (at intervals) for 180 miles in the Rustenburg and Pretoria districts, 100 miles in the Lydenburg and Peitersburg districts, and some 40 miles in the Potgietersrust district. As it probably persists on the dip for scores of miles the tonnage of ore on it is almost beyond calculation. It attains its best development in the Rustenberg and Lydenburg districts. The ore contains considerable amounts of nickel and appreciable quantities of gold but it is valuable chiefly for the platinum metals content. The platinum metals of the ores range from a trace to as much as 13 ounces a ton in picked specimens. Over considerable areas in the Rustenburg district, this horizon carries an average of 6 dwt. of platinum metals over a stoping width of 30 inches and an average of 10 to 12 dwt. over a milling width of 12 inches. Palladium is also present; the proportion of palladium to platinum ranges from 12 : 76 to 62 : 38 and is highest on the Potgietersrust fields. The ratio of palladium to platinum is as much as 10 per cent less in oxidized ore than in the original sulphide, the former therefore appearing to be more soluble. There are also subordinate amounts of rhodium and osmiridium.

Australia

Platinum is recognized in several districts in Australia, the most important deposits, however, occurring at Fifield and Platina, 54 miles northwest of Parkes, in New South Wales. These deposits are about 1½ miles apart; and the pay gravels, 6 to 13 feet thick, rest on shales and sandstones of Silurian and Devonian age, which are cut by diorite. The producing area is about 1 mile long and 60 to 150 feet wide and has an overburden 10 to 70 feet in thickness. The crude platinum is said to contain 75 per cent platinum metals, and an analysis shows the following.27/

Analysis of Crude Platinum, Fifield District,
New South Wales, Per Cent

Platinum	75.90	Iron	10.15
Iridium	1.30	Copper	.41
Rhodium	1,30	Gold	None
Palladium	Trace	Lead	Trace
Osmiridium	9.30	Silica	1.12
			99.48

27/ Hill, James M., Platinum and Allied Metals: U.S. Geol. Survey, Mineral Resources of the United States, Part I, 1916, pp. 13-14.

The gravels from the Fifield district have carried as much as 6 dwt. of platinum and 2 dwt. of gold per ton, but it is thought that the richer deposits are now worked out.

Platinum is frequently found in beach-sand deposits, along with gold, tin, and monazite, on the northeastern coast of New South Wales and the southeastern coast of Queensland, notably at Ballina, at the mouth of the Richmond River, at Evans Head farther south, and between Southport and Currumbin, near the mouth of the Tweed River. The sources of the metals are uncertain, the deposits are low grade, and the output has been very small.

In the Broken Hill district, platinum has been proved to extend over a considerable area in a copper-nickel gossn, closely associated with gabbro, decomposed gneisses, and schists. The deposits bear some resemblance to the nickel deposits of Sudbury, Ontario, and the platinum occurs combined with arsenic, as sperrylite.

Platinum metals are also known to occur in Queensland and Victoria, though the production from these States has been exceedingly small.

Mining.- Practically the entire output of platinum metals in Australia is from alluvial and beach-sand deposits. In the Fifield district shafts are sunk to the pay gravel, which is hoisted to the surface and washed by hand methods. Lack of water in this district has retarded large-scale development and prohibits the use of dredges. The beach-sand deposits are worked mostly by hand, the use of small power plants being restricted to one or two locations.

Production.- The deposits in the Fifield district were first exploited in 1894; and from that year until 1909 the total output of platinum from New South Wales was 11,138 troy ounces, an average of 742 ounces annually for the 15-year period.

In 1909, the first year for which production figures are available for all of Australia, the output was 440 ounces. From then on until 1927 the output never exceeded 796 ounces (1920).

The question of the refining of platinum in Australia has been considered from time to time, but no definite action has been taken, and the entire output is sent to England for refining. With the exception of the Bald Hill district in Tasmania, which, however, produces osmiridium, the future production of platinum in Australia is not promising.

Canada

With the exception of a very few ounces of platinum obtained from the black sands of British Columbia, all the Canadian platinum and allied metals are obtained from the treatment of the Sudbury copper-nickel matte. The precious metal residues are allowed to accumulate over irregular periods before they are treated, so that recoveries do not bear any definite relation to the quantity of matte treated in any particular year.28/

28/ Mineral Industry, Platinum-Group Metals: New York, vol. 37, 1929, p. 492

The platinum metals are found mostly as sperrylite, associated mainly with chalcopyrite. The ores recovered consist principally of chalcopyrite, pyrrhotite and pentlandite, in which the metallic platinum, gold, silver, and palladium occur.

The following is a typical analysis of this complex ore:

Analysis of Sudbury Copper-Nickel Ores[1/]

	Per cent		Ounce
Copper	1.11	Platinum	0,0068
Nickel	1.95	Gold	.022
		Silver	.223

1/ Canadian Mining Institute, Bull. 63, 1918, p. 99.

Platinum is found in a number of lacalities in Canada associated with auriferous gravels; but the crude metal has only been obtained from the Tulameen River district of British Columbia, where mining is still carried on by a few individuals, principally Chinese who work during the summer months only. Many of the richer placers have become exhausted, and the few that are now being worked are on benches 50 to 100 feet above the creek bottom. The heavy minerals remaining with the platinum are titaniferous magnetite, chromite, and native copper. The chromite may be intergrown with the platinum, which is sometimes magnetic due to adhering particles of magnetite. Olivine and pyroxene are also likely to be present in the sands.

The following is a typical analysis of crude platinum from this district:

Analysis of Crude Platinum from British Columbia[1/]

	Per cent		Per cent
Platinum	72.07	Osmiridium	10.51
Palladium	.19	Copper	3.39
Rhodium	2.57	Iron	8.59
Iridium	1.14	Gangue (chromite)	1.69

1/ Lumb, A. D., The Platinum Metals: Imperial Inst. Monograph, London, 1920, p. 22.

Production.- The occurrence of platinum in Canada was first observed in 1862, in the course of gold-mining operations. The following Table 25 shows the value of platinum minerals produced in Canada from 1887 to 1908, from placer deposits. Subsequent to 1909 no record has been kept of the quantity produced.

Table 25.- Placer Production of Platinum in Canada.

Year	Value	Year	Value
1887	$5,600	1898	$1,500
1888	6,000	1899	825
1889	3,500	1900	Nil
1890	4,500	1901	457
1891	10,000	1902	46,502
1892	3,500	1903	33,345
1893	1,800	1904	10,872
1894	950	1905	500
1895	3,800	1906	5,652
1896	750	1907	Nil
1897	1,600	1908	Nil

Sierra Leone

Alluvial platinum was discovered in June, 1926, in the gravels of streams draining the norite rocks of the Peninsula of Sierra Leone. Upon further work in 1927 alluvial platinum was found to be widely distributed, and promising deposits were located in the York district.[29]

The platinum occurs in the native state associated with ilmenite, magnetite, and scanty chromite. It is found in the form of small nuggets, as small pitted grains, and as crystals in the gravels of the streams and alluvial flats, and in beach gravels. Two nuggets—one weighing 7.4 grains and another 1.66 grains—were found in the branch of the Big Water heading from York Pass. An analysis of the crude platinum from this stream gave platinum 87 per cent, osmiridium 1.3 per cent, palladium 2 per cent, and iron 9.9 per cent.

As regards occurrences of platinum in situ, no systematic examination of the rocks for platinum has been made, but assays of some 15 samples of different types show up to six grains of platinum metals per ton, and the average is between 1 and 2 grains per ton. The streams carrying the best values have their source in, or cut across in their upper reaches, an intrusion of coarse-grained anorthosite and anorthositic gabbro situated between Good Luck Hill and York Pass. Sulphides are rare and are most prominent between Bura Town and Kent in certain very coarse-grained dykes which penetrate banded troctolite. The sulphides are chalcopyrite, pyrite, and pyrrhotite. Three assays of these sulphide-bearing rocks showed less than 2 grains of platinum per ton.

Germany

Just before the World War deposits of platinum were reported as occurring in the Lower Rhine region of Germany. This area lies in southern Westphalia, 20 to 30 miles east of Cologne, and includes the towns of Freudenburg, Siegan,

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29/ The Mining Journal, London, November 2, 1929, p. 891

and Meschede in Sieganland, as well as parts of Sauerland and Westerwald.[30] The platinum occurs in a series of fragmentary sediments, including principally slates and graywackes (quartz and slate cemented by argillaceous matter). It is also occasionally found in the recemented fragments which are presumably derived from the basal granite formation, underlying the platinum series. The platinum, which is present in a very finely disseminated state, is associated with other metals, some of which appear to have been introduced by solutions at a stage subsequent to sedimentation. Because of their similarity with Russian formations it is thought that the original source of the platinum was peridotite or other forms of basic igneous rock.

Ethiopia (Abyssinia)

One of the newly opened sources of platinum supply is in Abyssinia. The first production in this country was stated to be 40 pounds in 1926, increasing to 100 pounds in 1927, 200 pounds in 1928, and about 400 pounds in 1929. Several important concessions have been granted in recent years, and two are now in operation.

In the Province of Beni Shangul in central-western Abyssinia a concession was granted to the Deutsches Studiensyndikat of Stuttgart, Germany. This concession provides for prospecting and exploitation of all minerals, including gold and platinum, in the allotted area. Deposits in this district are mostly in river beds, and usually at a depth of 3 to 6 feet, mining and washing are carried on by natives. Samples of crude platinum from this district have been analyzed and found to contain 70 per cent platinum, 10 per cent gold, 7 per cent iridium, 3 per cent osmium and, 10 per cent palladium.

Other important concessions, controlled by Alberto Prasso (an Italian by birth), are situated in the Province of Beni Shangul and in the adjoining province of Walega, The deposits are similar to those controlled by the German concern, and several of them have been in production since 1928, the work being carried on by hand methods by natives who are paid the equivalent of 50 cents a gram of gold or platinum. According to the terms of these concessions, 10 per cent of the output is given to the Ethiopian government.[31]

Another occurrence of platinum in Abyssinia which apparently has not been worked as yet is in the province of Walega, south of the concessions held by Prasso. These deposits are situated on the Birbir River and are similar to those in the Ural Mountains, in that there is a central body of dunite, surrounded by a belt of pyroxenite, which in turn is surrounded by gabbro. There are two distinct dunite centers, called Youbdo and Sodo, respectively; they are separated by red quartzitic rocks composed of disintegrated dunite, called birbirite. The crude platinum in these deposits is also similar to that from the Urals in that it is rich in iron and poor in osmium. It has never been found in situ but occurs in small quantities in the debris or laterite derived from the weathering of the birbirite.[32]

30/ Mineral Industry, vol. 23, 1914.

31/ Commerce Reports, October 7, 1929, pp. 30-31.

32/ Duparc, L., and Molly, E., Les gisements platinifere der Birbir (Abyssinia): Bull. Suisse de Min. et Petrogr. vol. 8, no. 1, 1928, pp. 240-57.

ORGANIZATION OF THE PLATINUM INDUSTRY

The marketing of refined platinum is largely in the hands of the large refiners. These same refiners also are the principal buyers of crude platinum. Platinum-group metals are recovered as by-products from the electrolytic refining of copper as well as gold and silver bullion from various sources, but most of the copper and lead smelters are not in a position to make payment for the platinum content of ores.

Due to the wider use of the platinum metals in jewelry the number of refiners is somewhat larger than it was before the war, but even now the bulk of the platinum consumed in the United States is handled through only three or four firms. The largest two firms, Baker & Co. (Inc.), and the American Platinum Works, both of Newark, N. J., specialize in the refining and working up of platinum metals, but other firms also work up various kinds of jewelers' sweeps and precious metal-bearing material of various kinds. One firm, J. Bishop & Co. of Malvern, in addition to platinum ware manufactures articles of tantalum.

Before 1903 the platinum market was largely controlled by Johnson, Matthey & Co., a British firm, but about that year a French company, Societe Anonyme d'Industrie du Platine, came into prominence. Under the leadership of this firm, which built its own refinery at St. Denis (near Paris), an international syndicate was organized which included Johnson-Matthey, Heraeus, (the principal German refiner), Baker & Co. (the largest American platinum firm), and others. This syndicate was able to exert a powerful stabilizing influence on prices until it was disrupted by the outbreak of the World War in Europe. The subsequent progress of events is thus described by Wagner:[33]

> During the war this international selling organization was dissolved, but soon after the Armistice another powerful syndicate was formed to take its place. It is composed of Messrs Johnson Matthey, Ltd., London; Baker of New York; Heraeus of Hanau; and Maret and Bonnin of Paris; the three first-named firms having also been members of the original French syndicate. Up to March 1927 the market was largely controlled by the syndicate, which allotted quotas to each of the big producers and purchased their quotas at prices agreed upon, on condition that no platinum was sold directly to outside buyers. The quota allotted to the Soviet Government for 1927 was between 60,000 and 70,000 ounces, at the then price of 22 per ounce. As, however, the Uralian production for the year was estimated at 100,000 ounces, the Soviet representatives demanded a larger allotment, whereas the syndicate, in view of increased production elsewhere, considered that even the quota they had given them was too high and desired to reduce it. In consequence the agreement was not renewed and the Soviet output was put on the market in direct competition with the syndicate; the Rusplatina, an

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33/ Wagner, Percey A., The Platinum Deposits and Mines of South Africa: Edinburgh, 1929. p. 290.

organisation in which the monopoly for the exploitation of the Ural platinum deposits is vested, having for this purpose called into being a selling organisation, the Edelmetalle-Vertriebs Aktiengesellschaft, with headquarters in Berlin and branches in London and New York.

The Rusplatina's activity produced a sharp drop in the price of the metal, but the market soon adjusted itself and remained stabilized at a much lower level($72.00 an ounce as compared with over $100.00 in January) until the end of the year.

With the advent of increasing supplies from South Africa and in view of the prospects of still greater accessions of supply as a by-product of nickel-copper mining at depth in Canada, further efforts were made to include the Russian production within an international agreement governing prices and production, but without apparent success up to the date of this report (August, 1930).

The Uralplatina, which is the state trust in charge of the platinum industry in Russia, was discontinued as a separate organization in October, 1928, and was consolidated with the SoyuzZolota, the state trust in charge of gold mining, in order to consolidate the handling of all the precious metals under a single head.34/ This trust was organized in 1921, with headquarters at Sverdlovsk, and controlled the six important platinum-bearing districts of the Urals, and the two refineries at Sverdlovsk and Moscow. It did not, however, have the right to market the platinum, which was at first under the control of the syndicate mentioned above, and after March, 1927, was controlled by the Rusplatina.

MARKETING

There are no regular schedules of payment for the platinum content of ores, such as apply to the purchase of the gold and silver content of lead, copper, and so-called "dry" ores by American smelters. The regular platinum refiners usually require a minimum content of 60 per cent platinum-group metals in material they purchase, and hence it is often difficult to market platinum-bearing ores or concentrates; and even metallic material that contains considerable quantities of platinum can often be sold only at a substantial discount. In all cases it behooves the seller to clean the metal as thoroughly as possible before attempting to market it. In the case of placer material sand grains should be completely removed.

According to Hill:35/

> Crude platinum is sold in lots ranging from less than an ounce to hundreds of ounces; buyers, however, prefer not to handle lots of less than 2 oz. For small lots settlement is usually made on the basis of recovered precious metals, each

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34/ Kunz, George F., Platinum-Group Metals: Mineral Industry, 1928, vol. 37, New York, 1929, pp. 494-495.

35/ Hill, J.M., Platinum Metals chapter; Spurr and Wormser's Marketing of Metals and Minerals: New York, 1925, pp. 144-149.

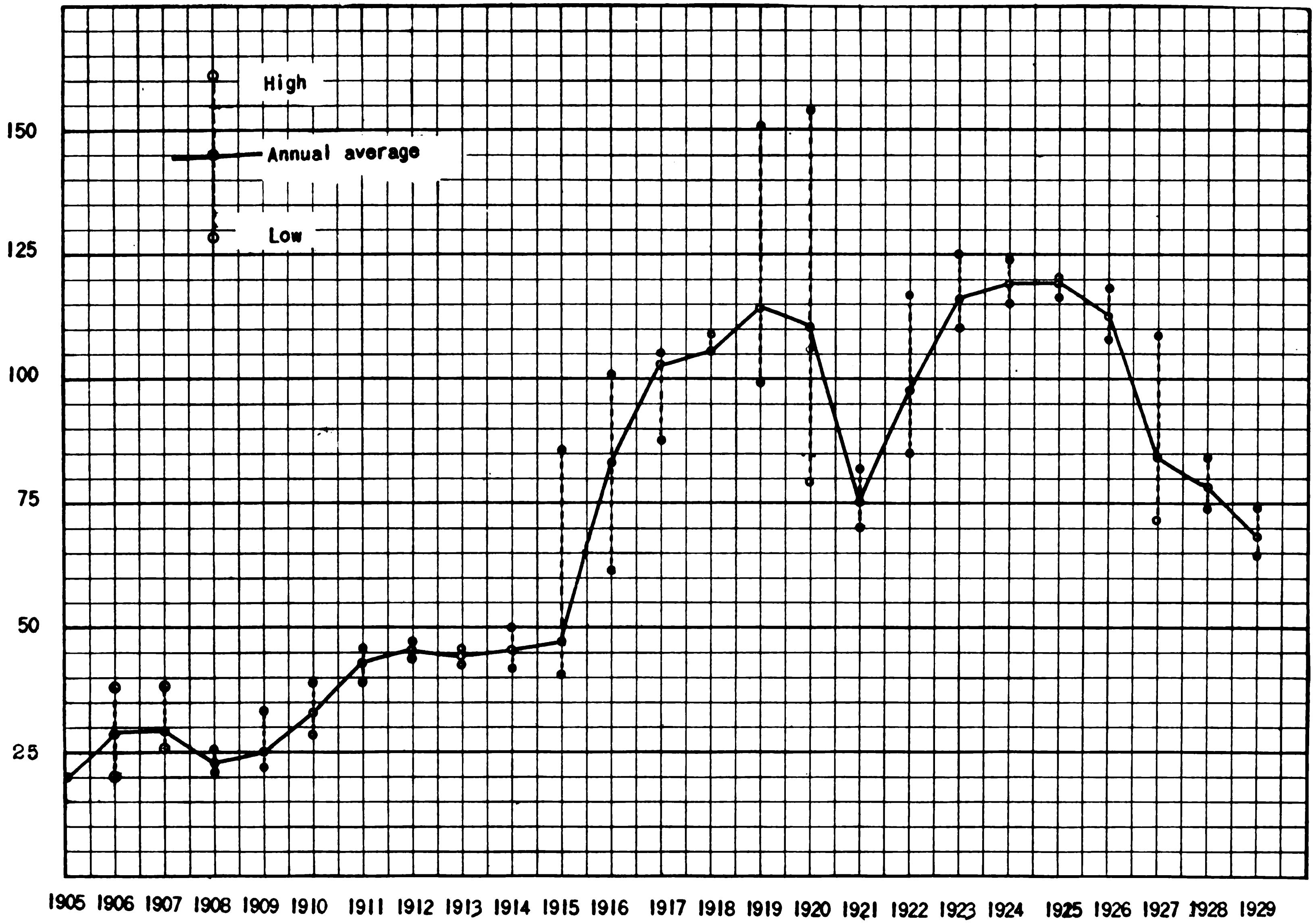

Figure 3.- Average price per troy ounce of platinum at New York, 1905 to 1929

metal being paid for at the market price. Large lots are usually offered with an assay certificate from a reputable chemist. Sometimes sale is made on the basis of this assay, but more often on an adjustment of the seller's assay and an assay of a sample taken in the presence of the buyer. As the actual recoveries seldom equal the content shown by assay, some sales are made on a figure which is the average of the assay content and actual recovery. The latter method is not liked by sellers. As all crude platinum carries appreciable quantities of palladium and iridium, and some of the rare elements of the platinum group, as well as more or less gold and silver, all the precious metals are shown in the analysis and should be paid for by the purchaser.

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As the platinum metals are very heavy, the volume of a package containing several hundred ounces is not large. Adequate packing for shipment to prevent loss is important. Shipments of large size from South America are often doubly wrapped in specially tough, semi-glazed paper, sewn into tightly woven cotton cloth, which, in turn, is sewn into canvas and sealed. This package is placed in a box made of 7/8-in. boards to fit the parcel exactly, put together with screws, the heads of which are deeply countersunk and the holes above the screw head filled with sealing wax. For small shipments such elaborate packing is possibly not necessary, though every precaution against loss through breakage of the wrappings should be taken. Domestic platinum shipments are usually made either by insured parcel post, or express, the rate varying from one-half of 1 per cent to 1 per cent of the value. Insurance companies will insure shipments to and from foreign countries at a usual rate of one-half of 1 per cent, though some rates are lower.

PRICES

Ever since platinum became a commercial metal its price has fluctuated rather widely and irregularly. In the absence of a duty and since the domestic supply is so largely imported prices in the United States follow London quotations; but the market for platinum, both crude and refined metal, is very sensitive and prices vary from day to day. Offers to buy or sell, therefore, are usually subject to immediate acceptance on a cash basis.

In 1883 the price of platinum was as low as $5.49 a troy[36] ounce (480 grains or 31.10 grams) but it rose rapidly, though irregularly, until by 1901 it began to approach the price of gold. Beginning with January, 1906, platinum has consistently been worth more than gold and it is significant that this date marks practically the beginning also of the use of platinum in jewelry.

The sharply upward trend, begun in 1906, received a heavy set back in 1906, received a heavy set back in 1908 due to increased production and lack of consumptive demand for sulphuric acid manufacture and other industrial uses but tho rising movement was soon resumed and continued until 1910, after which and until 1914 the London price was stabilized around 180 s. ($44.) and the New York price hovered usually around $45. an ounce.

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[36] Day, David T., Mineral Resources of the U. S., 1888, p. 166.

Since the outbreak of the World War in Europe the general course of platinum prices has been a steady upswing followed by a fairly steady decline. The major movement was abruptly interrupted by the general industrial depression in 1921 and the wide spread between high and low records for the years 1919 and 1920 and also 1927 tended further to obscure the general trend, as revealed by the accompanying graph (fig. 3), showing the average annual prices. The average prices were substantially higher from 1923 to 1926, inclusive, than ever before, but the high point in these years ($125 in 1923) was very much lower than the maximum of over $154 attained in January, 1920.

The sharp break in 1927, from $112 at the beginning of the year to $72 in June, was due to the failure of the syndicate to control the Russian output and the selling pressure of the newly formed Rusplatina. In 1928 successive increases during January brought the price for a few days to a maximum of $90, but this recovery was of short duration and by the autumn of 1929 the quotation had slowly declined to $65. During the first half of 1930 the dominant movement was accelerated, and by July platinum was selling at under $45 an ounce.

In general the prices of the platinum metals follow the course of the platinum market. Palladium in recent years has been generally about $25 or $30 an ounce cheaper than platinum. Iridium sponge and powder, the third in point of consumption, is always the most costly of the group, but the quotations are quite erratic, often fluctuating quite independently of the price of platinum. In 1928, for example, refiners reported sales at prices ranging from as low as $175 up to $500 an ounce, the average for the year being $294.[37] Rhodium, nominally at least, used to be worth considerably more than platinum, but it declined rapidly in value from about $150 an ounce early in 1922 to $40 an ounce toward the end of 1928. During the first half of 1930 the price was generally $45 to $50. Osmium quotations reached a peak of $115 in 1925. After dipping below $60 in 1929 they rose to $70 to $75 in 1930. Ruthenium also reached its high point ($105) in 1925; in July, 1930, it was quoted at $40 to $42 an ounce.

37/ Kunz, George F., Platinum Group Metals: Mineral Industry during 1928, p. 491.

Table 26.- Average Monthly Prices of Platinum at New York, 1905-1928, Dollars per Troy Ounce 1/

Month	1905	1906	1907	1908	1909	1910	1911	1912
January	19.50	20.50	38.00	25.50	24.10	29.00	39.06	46.00
February	19.50	25.00	38.00	25.50	24.00	28.75	39.81	45.63
March	20.50	25.00	37.00	25.50	33.75	29.13	41.00	45.50
April	20.50	25.00	32.50	23.50	23.50	29.25	41.35	45.50
May	20.50	25.00	29.50	22.50	23.25	29.55	42.81	45.50
June	20.50	25.40	26.20	23.50	22.75	31.38	42.88	45.50
July	20.50	26.00	26.75	20.00	22.43	33.00	42.95	45.50
August	20.50	26.00	28.13	18.75	22.65	33.00	44.38	45.50
September	20.50	32.10	28.70	20.00	25.31	33.63	45.31	45.50
October	20.50	33.00	27.13	21.50	27.75	37.50	46.25	45.50
November	20.50	35.50	26.31	24.00	29.50	39.44	46.13	45.50
December	20.50	38.00	26.00	24.00	29.50	38.75	46.00	45.50
Average for year	20.33	28.04	28.18	22.85	24.87	32.70	43.12	45.55

Month	1913	1914	1915	1916	1917	1918	1919	1920
January	45.50	43.38	41.10	90.05	87.83	105.92	104.85	154.23
February	45.50	43.50	40.00	90.00	103.75	107.68	100.43	151.59
March	45.50	43.50	39.50	90.75	104.33	108.00	99.20	138.56
April	45.50	43.50	38.63	83.10	103.77	108.00	99.85	127.04
May	45.50	43.50	38.50	80.50	105.00	106.27	102.60	97.50
June	45.50	43.50	38.00	78.13	104.75	105.00	105.80	85.19
July	45.50	43.50	38.00	63.60	103.88	105.00	105.90	83.94
August	44.90	50.20	39.25	62.56	104.55	105.00	107.60	111.44
September	43.96	50.00	50.00	84.25	104.13	105.00	128.70	115.20
October	44.00	49.50	54.50	89.75	104.00	105.00	132.21	101.70
November	43.70	45.45	62.63	101.25	104.52	105.00	136.74	84.75
December	43.45	42.19	85.50	86.87	104.38	105.54	151.35	79.62
Average for year	44.88	45.14	47.13	83.40	102.82	105.95	114.61	110.90

Month	1921	1922	1923	1924	1925	1926	1927	1928	1929
January	73.40	97.26	112.46	122.12	117.00	118.20	109.52	79.28	74.00
February	70.23	89.54	113.27	124.74	117.00	113.91	107.55	84.78	70.00
March	72.46	87.50	110.85	121.69	117.00	112.00	108.00	80.00	70.00
April	73.40	87.50	116.84	115.58	118.27	111.54	101.89	80.00	70.00
May	73.74	85.53	115.01	115.73	119.85	108.96	84.68	78.00	70.00
June	74.95	87.21	115.61	116.00	120.00	111.00	72.00	78.00	68.00
July	70.44	90.18	116.00	118.23	120.00	114.69	72.00	78.00	68.00
August	73.22	98.37	116.00	120.00	120.00	116.00	72.00	78.00	68.00
September	75.96	117.28	116.00	118.92	120.00	116.84	72.00	78.00	68.00
October	81.80	109.44	116.92	118.00	120.00	112.24	72.00	78.00	65.00
November	82.60	108.00	124.48	117.79	120.00	112.00	72.00	76.41	65.00
December	78.19	113.60	125.00	117.00	120.00	111.85	72.00	74.48	65.00
Average for year	75.03	97.62	116.54	118.82	119.09	113.27	84.64	78.58	63.75

1/ Engineering and Mining Journal, Annual, New York

COSTS AND INTERNATIONAL COMPETITION

As long as the Russian Soviet authorities decline to adhere to a policy of cooperative action in sustaining prices by means of an international cartel, costs of production tend to regulate the relative distribution of output by countries. At prices above $75 (taking a high figure) the world's capacity to produce platinum is substantially in excess of its present ability to absorb the metal.

The situation in Russia is complicated by the novel economic organization under the existing Soviet regime and the national need to extablish foreign credits, but elsewhere platinum can not be produced for very long after the producers fail to get back at least a new dollar for every dollar they spend on operating expenses. By-product and secondary platinum also may be mentioned. As previously noted, the amount of by-product platinum produced in the United States is too small materially to influence world conditions, but the impending contribution by the International Co. from Canadian nickel-copper ores may considered as being a permanent factor in the market so long as the major products, copper and nickel, continue to be produced.

If one accepts Wagner's estimates of costs the first of the large producers to curtail operations would be Colombia. He reports[38] that costs both in Colombia and in the Uralian fields are probably not less than $50 (£10) an ounce and since the Colombian producers have no means whereby losses can be nominally absorbed within a national exonomic structure they would doubtless cease producing when and if prices remain much below this level. South African costs, according to the same authority, vary. At Onverwacht costs exclusive of administrative expense, directors' fees and Government taxes fluctuated from £3 9s.11d. when treating high-grade ore to £10 4s.9d. when treating low-grade ore. For the fiscal year ended June, 1928, the average, exclusive of such overhead charges, was £6 18s.9d. and, including these charges, £7 5s.10d. or approximately $35.50 an ounce. At another olivine-dunite property (Mooihoek-Driekop mine) the operating cost during the same period was £7 0s.10d.; and the total cost, including an abnormally high overhead due to small-scale operations, was £8 16s.10d., or approximately $39.10 an ounce. For properties operating in the Merensky horizon the estimate is £6 or, say, $29.20 an ounce.

IRIDOSMINE OR OSMIRIDIUM

In 1804, Smithson Tennant, a British scientist, first announced the existence of two metallic substances of the platinum group known as iridium and osmium; and one year later, it was discovered that the two substances were usually found combined together in a rare metal generally but not always associated with platinum. This new alloy was called iridosmine, or osmiridium, as it is known in mining circles.

While iridosmine is widely distributed it is found in sufficient quantity to mine in only two localities, Tasmania and the Witwatersrand (Union of South Africa).

38/ Wagner, R. A., Work cited, p. 291.

Tasmania

General.—Osmiridium is the only platinum metal that is produced in any quantity in Tasmania and comes from the Bald Hill district near Waratah, in the northwestern part of the State. The principal deposits in this district are on the Nineteen-Mile Creek and its tributaries, Linger-and-Die, McGinty's, and Barren Creeks and on the Savage River.[39]

It has been located in situ in the rocks of Bald Hill, principally in serpentine, but also with chalcedony and opaline silica in lode formations. In the former it is associated with magnetite, pyrite, pyrrhotite, nickel and gold. The osmiridium in the placer deposits is sometimes coated with iron oxide and is also at times found enclosed in chromite. The following analysis of this metal is typical of the Bald Hill district:

Analysis of Bald Hill Crude Osmiridium, Per Cent

Osmium	57.09	Palladium	o.21
Iridium	33.80	Gold	.04
Platinum	.37	Iron	.30
Ruthenium	8.19	Copper	Trace

Other localities in Tasmania at which osmiridium has been located are Heazlewood, Whyte, Castray, Huskisson, Wilson, and Boyes Rivers; the Badger gold diggings, west of Savage River; and the Salisbury goldfield near Beaconsfield.

Mining.—In the Savage River Valley district, alluvial mining in the river beds can be done to any great extent only in summer, when the water is low. In the Wilson River district, where the fields are in a more elevated position, the creeks are generally dry in summer and are usually worked in winter by miners from the Savage River district. In the valley of the Nineteen-Mile Creek, work goes on all the year round, and here the most of the permanent camps are to be found. The general seasonal nature of the mining has a distinct influence on output, which makes the supplies coming from Tasmania somewhat erratic and uncertain.

Production.—The following Table 27 shows the production of osmiridium in Tasmania from 1910 to 1928, inclusive.

The first reported production of osmiridium from Tasmania was in 1910, when 120 troy ounces were produced. From then on until the World War production advanced rapidly, until in 1914, 1,018 ounces were produced. The war at first had an adverse effect upon output, which fell to only 222 ounces in 1916, but as osmiridium was needed for munitions and other war purposes manufacturers who founc their other sources curtailed later turned to Tasmania for their supplies, and by 1918 production advanced to 1,607 ounces. From then on the output has fluctuat ed between 365 ounces (1924) to 3,666 ounces (1925).

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[39] Brown, Campbell, A Review of the Osmiridium Mining Industry of Tasmania: Tasmania, 1919, 24 pp.

Table 27.--Production of Osmiridium in Tasmania 1910-1928, Troy Ounces

Year		Year	
1910	120	1920	2,009
1911	271	1921	1,751
1912	778	1922	1,174
1913	1,261	1923	673
1914	1,018	1924	365
1915	247	1925	3,666
1916	222	1926	3,172
1917	332	1927	633
1918	1,607	1928	1,627
1919	1,670		

Union of South Africa.--Osmiridium has been known to exist in the Witwatersrand district of the Transvaal since its discovery in 1892, but only after the amalgamation process for the recovery of gold was abandoned was there any effort made to recover the osmiridium. In 1922 preliminary concentration on corduroy and blankets was put into use and the recovery of these metals became practicable. Now the recovery of osmiridium has become an integral part of the dressing operations.

As to the distribution of the osmiridium in the conglomerates of the Witwatersrand System, milling operations on a huge scale have definitely established that it is most abundant on the Far East Rand where the main Reef Leader is being worked, less abundant on the West Rand where the Main Reef and South Reefs are mined, and even less abundant on the Central Rand where all three beds of conglomerates are developed.[40]

Production.--Table 28 shows the production and sales of osmiridium in the Union of South Africa from 1921 to 1928, inclusive.

The major portion of this output is derived from the conglomerates of the Main Reef Series, the Main Reef Leader, as developed on the Far East Rand, being the principal source of production. Notable amounts are, however, also being recovered from the Kimberley or Battery Reef on the West Rand. On the Far East Rand the principal producers, in order of their productivity, are the Government Gold Mining Areas, New Modderfontein, Modderfontein B, Brakpan, and Modderfontein Deep Level Mines.

Practically all of the osmiridium produced in South Africa is sold outside the country for refining, England, France, Germany, and the United States purchasing the major part.

40/ Wagner, P. A., Work cited, p. 35.

Table 28.--Production and Sales of Osmiridium in South Africa, 1921-1928, Troy Ounces

Year	Production	Sales
1921	(1)	509
1922	(1)	761
1923	(1)	1,784
1924	(1)	5,763
1925	5,490	6,055
1926	6,228	6,360
1927	5,473	5,653
1928	5,948	5,913

(1) Not reported